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WATER QUALITY DATA DURING SEPTEMBER 16-19, 1974, AT SILVER BAY, SAWMILL COVE, AND EASTERN CHANNEL SITKA, ALASKA

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ALASKA
OPERATIONS OFFICE
AND REGION X
SURVEILLANCE AND
ANALYSIS DIVISION
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The waters of Sawmill Cove, Silver Bay and the contiguous reaches of Eastern Channel had not been sampled by a water quality regulatory agency since 1970. The study reported here was undertaken to determine the present quality of the waste-receiving waters and to determine the improvements, if any, that have occurred in water quality as a result of the installation of a primary treatment system for the removal of settleable solids at the Alaska Lumber and Pulp Company Mill. Data collected included temperature, salinity, dissolved oxygen, Secchi disk, conductivity, pH and sulfite waste liquor data.

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ALASKA OPERATIONS OFFICE

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A working paper presents results of investigations which are, to some extent, limited or incomplete. Therefore, conclusions or recommendations - expressed or implied- may be tentative.

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INTRODUCTION

Background

A study of the estuarine waters of Sawmill Cove and Silver Bay and the marine waters of Eastern Channel was made during the week of September 16, 1974. These waters are influenced by the waste discharges from the Alaska Lumber and Pulp Company, which is located at the head of Sawmill Cove about 3.5 miles southeast of Sitka, Alaska. (Figure 1). The Alaska Lumber and Pulp Company has a magnesium-base sulfite-process pulp mill that began operation in 1959 and produces an average of 638 tons of air dried dissolving grade pulp per day. The average wastewater discharge from the mill to Sawmill Cove amounts to 31 million gallons per day. The original plan was to build a 300-400 ton per day mill, but this plan was later amended to ultimately build a mill which would provide 600 tons per day. Several years prior to operation of the pulp mill, Sawmill Cove and Silver Bay had only one source of man-induced pollutants, a sawmill which created an accumulation of sawdust, pieces of bark, and wood scraps from associated logging activities, which in turn had become deposited on the bottom of the bay. At the time of a 1956-1957 study these accumulations had been judged to have only a slight effect on the quality of the adjacent water (1). One of the significant findings of this study, which was made prior to mill construction, was the widespread occurrence of hydrogen sulfide in bottom deposits throughout most deep water locations in the bay. Hydrogen sulfide was not noted, however,

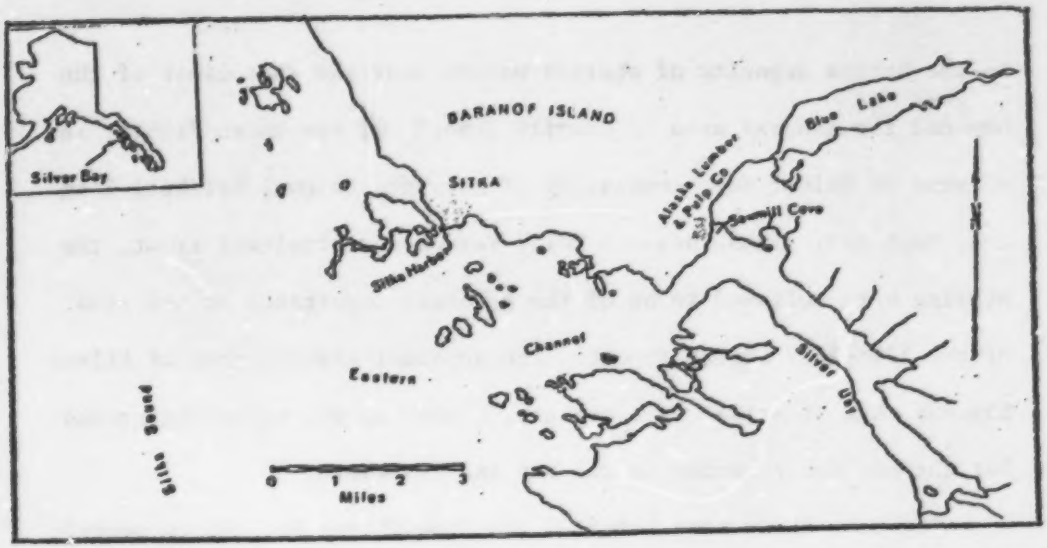

Figure 1. The Silver Bay, Sawmill Cove, Eastern Channel Study Area.

in the bottom deposits of shallow waters near the shorelines of the bay and the general area of Sawmill Cove.* Of the known fishery resources of Silver Bay, consisting of herring, salmon, halibut, ling cod, rock cod, crabs, sea-run Dolly Varden and steelhead trout, the herring were believed to be of the greatest importance at the time of the 1956-1957 survey report. The apparent significance of Silver Bay was that it served as a nursery, wintering and schooling ground for the herring produced in the bay and elsewhere.

The same study also revealed that the Silver Bay system contributed substantially to the commercial fishery of the Sitka area, the primary industry prior to the construction of the pulp mill. This contribution of the bay occurred in three ways: one, directly through spawning and production of salmon in tributaries, two through utilization of bay waters as a nursery and wintering area for salmon and/or herring, and three, through production of herring known to occur at the mouth of Silver Bay, and in the areas of Sawmill Cove and an adjacent embayment called Herring Cove (Figure 1).

Of equal significance in the 1956-1957 study were data on water quality at a mid-channel location off Point Bucko (Station 16) prior to mill construction. In water at two feet and 100 feet deep, about 0.4 mile from the location of the future mill outfall, temperatures

*Hydrogen sulfide was not measured quantitatively during this study; thus only qualitative assays were made and they were based on odor of the deposits and low dissolved oxygen concentrations in the water above the deposits.

ranged from 2.5 to 15.5° centigrade; salinity from 11.1 to 32.7 parts per thousand; dissolved oxygen from 6.7 - 13.6 milligrams per liter (mg/l) and pH from 7.8 - 8.6. The five day biochemical oxygen demand (BOD 5) was less than 2.0 milligrams per liter.

Herring still are found in much of Silver Bay, but as late as 1971 sometimes had experienced extensive mortality in Sawmill Cove due to exposure to sudden releases of hydrogen sulfide from massive bulking of sludge deposits that contain this toxic substance.* In addition to contributing to reduction and bait fisheries, herring provide food for man, salmon, and halibut. Thus the use of Silver Bay waters as a nursery area for pink, chum, and silver salmon and as a spawning site and a winter niche for herring was quite important.

The construction and subsequent operation of the pulp mill by the Alaska Lumber and Pulp Company in 1959 brought about several attendant changes in the Silver Bay area. One of these is the storage of logs throughout much of Sawmill and Herring Coves, and at two other sites elsewhere in Silver Bay. In Sawmill Cove the storage and subsequent handling of logs has resulted in the loss of wood solids (bark, wood scraps, limbs and wood slivers), and some water-soaked whole logs that have sunk to the bottom and contributed to the formation of thick sludge beds. In the upper reaches of this cove the accumulation of

*The last reported major fish kill of this nature occurred on September 11, 1970, two years prior to installation of additional wastewater treatment facilities described later in this report.

such debris with attendant loss of metal log bands and sludge build-up has been sufficient to require occasional dredging to prevent grounding of the logs in the area adjacent to the log bundle transfer facility. This facility lifts bundled logs from the water to a "dry" deck for debanding and sorting prior to their entry into the mill. The log bundle transfer facility was installed in 1968, and its use has retarded the rate of accumulation of lost wood solids and other debris in this reach of Sawmill Cove. Some of the sorted logs are rebundled then skidded back into Sawmill Cove for transportation as log rafts to a sawmill at Wrangell, Alaska. This skidding still results in some loss of wood solids in the upper reach of the cove.

In Herring Cove, log storage over the years has resulted in the accumulation of sunken, water-soaked logs so abundant in the extreme northern end of the cove that bottom sampling gear gets entangled therein. Divers are unable to thoroughly investigate the area because of poor visibility (2) and depth limitations. Poor light penetration is caused by high concentrations of sulfite waste liquor in the surface waters. This condition has contributed to the reduced dissolved oxygen in the northern and middle reach of this cove. Bundled logs are stored primarily in two other reaches of Silver Bay, but investigations of the effects of log storage at these sites have not been made. The predominant influences on water quality in Silver Bay, however, are those caused by wastewater discharges from the pulp mill rather than the associated log storage activities.

The present study of Silver Bay was conducted concurrently with an in-plant investigation of the quality of the waste discharges from the pulp mill. The investigation of mill discharges was accomplished to determine the compliance of these discharges with a waste discharge permit issued by the U.S. Environmental Protection Agency in October 1973. The EPA permit requires best practicable treatment by 1977 with effluent limitations on waste load discharges during the interim period. A state waste discharge permit was issued to the mill in 1971. It essentially required primary treatment of pulp processing wastewaters, installation of additional chemical recovery systems, treatment of domestic wastes, and studies for a deepwater outfall with a diffusor. Studies for a deepwater outfall were abandoned upon knowledge of issuance of the federal permit, but the other requirements of the state permit have by now been met.

The quality of the effluents discharged by the mill through its two outfalls during the week of September 17, 1974 were as follows:

Parameter	Average Concentration
Main Sewer	
5-day biochemical oxygen demand (BOD)	831 mg/l
Chemical oxygen demand (COD)	2804 mg/l
Sulfite waste liquor (SWL)	2176 mg/l
Total volatile solids (TVS)	2480 mg/l
Suspended volatile solids (SVS)	48 mg/l
Total solids (TS)	3100 mg/l

Total organic carbon (TOC)	2716 mg/l
Sulfides	0.2 mg/l
pH	4.1
Mercury	0.5 micrograms/liter (m/l)

Water Treatment Plant

5-day BOD	50 mg/l
COD	6 mg/l
SWL	2 mg/l
TVS	50 mg/l
SVS	2 mg/l
TS	79 mg/l
TOC	3 mg/l
Sulfides	0.2 mg/l
pH	5.0
Mercury	0.6 m/l

The average flow for these two waste streams during the same period respectively were 39.7 and 3.1 million gallons per day (mgd), or a total average flow of 42.8 mgd, except on 3 filter backwashing days per week when the flow from the water treatment plant is estimated to be 4.2 mgd. The discharge from the water treatment plant consists of filter backwash water plus leakage. The main sewer contains all other wastewaters from the mill, including wastewaters from the primary treatment facility, which was installed in September 1972, and domestic wastewaters from the secondary treatment and chlorination facilities which began operation in February 1973.

Chemical recovery is practiced at the Alaska Lumber and Pulp Company Mill. In this process strong pulping liquors are collected, concentrated and burned in special boilers. The desired end product in the process is partial recovery of magnesium oxide and sulfur dioxide which are re-cycled. Some chemical recovery was installed as part of the mill in 1959 and these recovery units were routinely by-passed because of the limited capacity of the recovery units and build-up of strong pulping liquors in the mill. Facilities for additional chemical recovery were under construction at the time of the 1974 survey. These have doubled the capacity for chemical recovery and were completed in December 1974. Barring major problems in the mill, there should by no by-passing and discharges of strong pulping liquors to the Silver Bay system in future years.

Purpose

The waters of Sawmill Cove, Silver Bay and the contiguous reaches of Eastern Channel had not been sampled by a water quality regulatory agency since 1970. The brief study reported herein was undertaken to determine the present quality of the waste receiving waters and to determine the improvements, if any, that have occurred in water quality as a result of the mill's installation of a primary treatment system for the removal of settleable solids from the pulp processing wastewaters.

The following questions were answered in whole or in part as a result of this study:

1. What is the present water quality in Silver Bay and Eastern Channel compared to previous studies, and to the Alaska Water Quality Standards criteria for dissolved oxygen, pH, residues, sludge deposits, and toxic substances (sulfite waste liquor)?

2. What improvements in water quality, if any, have occurred since installation and operation of a primary treatment system for the removal of settleable solids from pulp processing wastewaters?

3. What is the magnitude of the area of Silver Bay and adjacent waters of Eastern Channel that are affected by sulfite waste liquors discharged from the pulp mill?

Scope of Study

The Alaska Lumber and Pulp Company, in addition to installing a primary treatment system for pulp processing wastewaters, also installed a secondary treatment system for domestic wastewaters, but no attempt was made during the September 1974 survey reported herein to determine the influence of the latter system on water quality. Specifically, no bacteriological samples were taken. The contribution of these wastewaters on other water quality parameters, such as dissolved oxygen, was judged to be imperceptible.

Chemical, physical, and very limited biological data were collected from 23 stations in Silver Bay and the adjacent waters of Eastern Channel (Figure 2) concurrently with the in-plant compliance monitoring survey at the Alaska Lumber and Pulp Company. Both were accomplished during the week of September 16-19, 1974. No attempt is made herein to correlate the findings of the in-plant survey with those of the receiving water surveys. In the receiving waters, primary

efforts were made to collect temperature, salinity, dissolved oxygen, Secchi disk, conductivity, pH and sulfite waste liquor data.

Bottom samples in the study area were collected to determine visual presence of settleable solids in the form of pulp fibers as recently formed sludge mats, if any; for chemical composition to further characterize sludge formations known to be present during previous studies; for qualitative determinations of the occurrence of hydrogen sulfide; and for general biological information pertaining to macroscopic (readily visible) plants or animals that might inhabit the bottom deposits. No samples were obtained to evaluate floating or suspended macroscopic plant or animal populations.

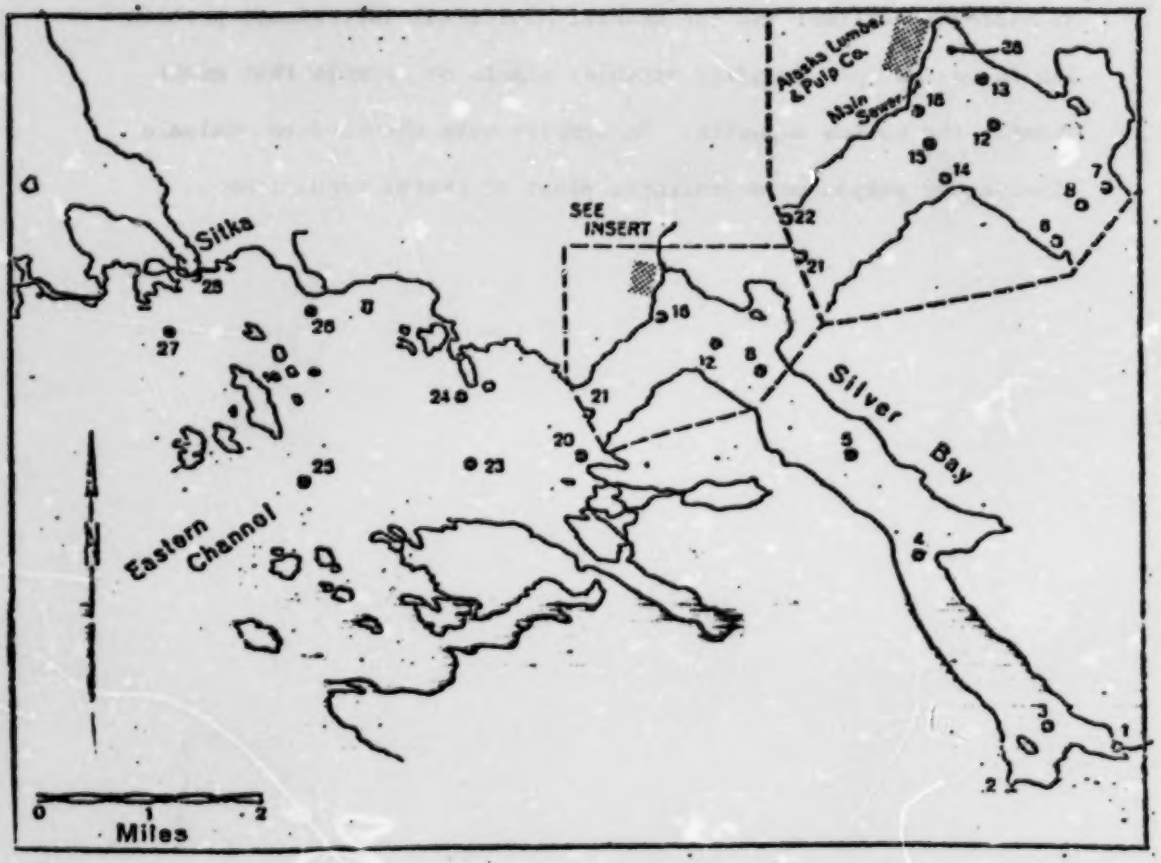

Figure 2. Sampling station locations in the Silver Bay and Eastern Channel Study Area, September 17-19, 1974.

SUMMARY AND CONCLUSIONS

A brief water quality survey was conducted near Sitka, Alaska, in the marine water of Eastern Channel, Silver Bay, and Sawmill Cove during the week of September 17, 1974, to determine the present water quality influences of waste discharges from the Alaska Lumber and Pulp Company following the installation and operation of a primary treatment system for pulping wastewaters, and to assay any associated improvements in these receiving waters. Data obtained from the survey of 5 stations in Eastern Channel, 16 stations in Silver Bay, and 1 station in Sawmill Cove consisted primarily of measurements for sulfite waste liquor, dissolved oxygen, temperature, pH and conductivity at depths of 1, 5, 10 and 12 meters. Transparency, chemical, visual, and qualitative biological examinations of bottom deposits were made at selected locations near the mill's main sewer.

The Alaska Water Quality Standards criterion for toxic substances in Class D and E waters is: Concentrations shall be less than those levels which cause tainting of fish, less than acute or chronic problem levels as revealed by bioassay or other appropriate methods, and below concentrations affecting the ecological balance. Sulfite waste liquors at concentrations of 50 mg/l are toxic to phytoplankton and fish-food organisms; at concentrations of 10 mg/l, they are damaging to some immature forms of shellfish.* Data from the survey reveal that:

*Forty-eight hour bioassays of effects of magnesium oxide base sulfite waste liquor show a 20 percent mean response at a concentration of 40 mg/l, but concentrations as low as 10 mg/l have produced toxic responses in as much as 5 percent of some populations sampled.

1. sulfite waste liquor (SWL) concentrations of 50 or more mg/l occurred in 14% (33) of all samples (232) taken at the 1, 5, 10, and 12 meter depths and 51% of all samples had SWL concentrations of 10 or more mg/l;

2. 42% of all samples from the 1 and 5 meter depths had more than 50 mg/l of SWL, and 98% had more than 10 mg/l;

3. 83% of the near-surface stations in the 11 square mile study area had concentrations of 50 or more mg/l of SWL at one time or another during the survey period, and 10 mg/l concentrations of SWL were observed throughout the 1-meter depth during the entire study or 98% of the time, except in only one instance, at Station 14;

4. no perceptible major improvements in the magnitude of concentrations of sulfite waste liquor concentrations in Silver Bay and the adjacent waters of Eastern Channel since the 1968-1969 study, as based on the similarities in SWL concentrations during the two surveys.

The same standards criterion for dissolved oxygen in Class D and E water is 6.0 mg/l. Data from the September 1974 survey and comparisons with pulp mill data and previous studies revealed that:

1. none of the stations sampled during September 17-18 had less than 6.0 mg/l;

2. from July 1972 - September 1974, dissolved oxygen was equal to or greater than 6.0 mg/l near the mill both prior to and after installation of the mill's primary treatment facility.

3. dissolved oxygen concentrations in surface and near surface waters of Silver Bay nearest the pulp mill's main sewer prior to installation of the primary treatment facility in late September 1972 were frequently less than 6.0 mg/l, and after installation they were increased significantly, but not enough to meet the 6.0 mg/l standard at all stations throughout the study area at all times at depths above 5 meters;

4. the continued but infrequent occurrence of dissolved oxygen less than 6.0 mg/l during periods of low stream discharge (during mid-summer and early fall) at the 1 meter depth was evidence that the improvements in dissolved oxygen following installation of the primary treatment facility is not complete.

All but 6% of the 231 pH measurements made during the September 17-18, 1974 survey were within the range of the 7.5 to 8.5 criterion prescribed by the Alaska Water Quality Standards. Seven of these 13 measurements were both more than and less than the range criterion and occurred at the uppermost reaches of Silver Bay, and one was above this range at Station 23 which also had two values below the limit on two other occasions. These stations are quite distant from the mill discharges, and the high pH values found there probably are a consequence of photsynthetic activity while the low pH values appear to be the result of pulp mill discharges, as was the case at Stations 12 and 16 which are quite near the mill's main sewer outfall.

Of the 36 Secchi disk readings to measure water transparency, none were less than the 1 meter criteria established by the Alaska Water Quality Standards, but SWL was sufficiently abundant that Secchi disk values were within 0.14 meters of exceeding this criterion.

There were no major improvements in the chemical characteristics of the 0.2 square mile sludge deposits in Sawmill Cove and the adjacent reach of Silver Bay as indicated by very high percentages of total volatile solids, organic carbon, organic nitrogen and sulfides, general features that were also found during a previous study in 1968-1970. The lack of major improvement in these characteristics was not unexpected, however, because the decomposition of the sludges under the anaerobic conditions that prevail therein requires a significantly longer period of time than the two year interval that has elapsed

since the installation and operation of the pulp mill's primary treatment facility which is designed to remove much of the sludge-forming settleable solids from the mill's wastewaters.

Hydrogen sulfide was noted in samples of the bottom sludges from Sawmill Cove and the adjacent reach of Silver Bay during the 1968-1970 study. It was not only grossly apparent in the bottom deposits, but also in the surface waters above the sludge beds which at that time also contained freshly deposited wood fibers. Floating mats of wood fibers and sludge that had bulked from bottom reaches, apparent during the 1969-1970 study, were not observed in September 1974. During the September 1974 survey, although the sludge samples had perceptible quantities of hydrogen sulfide but lacked freshly deposited wood fibers, hydrogen sulfide was not observed in the surface waters above these bottom deposits in either Sawmill Cove or Silver Bay. At the same time, pollution tolerant polychaete worms, found only in a few sludge samples in the 1968-1970 study, were found at several stations. These September 1974 observations, specifically the lack of recently deposited wood fibers on the sludge beds in Sawmill Cove and the adjacent reach of Silver Bay, the lack of hydrogen sulfide bubbles in surface waters above the sludge beds, the lack of floating wood fiber and sludge mats found during the 1968-1970 study, and a slight but perceptible increase in the occurrence of pollution tolerant polychaete worms, are significant because they indicate perceptible improvement in these environments since installation and operation of the mill's primary treatment facility. There remained, however, both a significant paucity in the variety

of bottom associated organisms in these reaches and no major change in the chemical characteristics of the sludge deposits, features indicative that the improvement process is nowhere near complete.

STUDY AREA

General Description

Silver Bay is an estuary connected with Sitka Sound by way of Eastern Channel. The bay is 6.8 miles long and varies in width from 0.4 to 0.9 miles. It is 120 meters deep at the mouth, decreasing to 45 meters near the head of the bay. The bay covers an area of about 4.2 square miles, and has about 30 miles of shoreline. There are a number of sources of fresh water entering Silver Bay. Three streams enter at the head of the bay, seven creeks enter between Bear Cove and Herring Cove, and Sawmill Creek enters at Sawmill Cove. Process water for the Alaska Lumber and Pulp Company is drawn from Blue Lake which is also the source of water for Sawmill Creek.

The Alaska Lumber and Pulp Company is located about 1.5 miles from the mouth of the bay. There are no residential areas or municipal developments near the mill. The mill is the only source of wastewater discharges to Sawmill Cove and Silver Bay.

Climatic Conditions

The Sitka-Silver Bay area is in the cold maritime belt of Southeastern Alaska and lies on the edge of the Alexander Archipelago. Average annual precipitation is near 100 inches, and annual snowfall is less than 100 inches. Prevailing winds generally are off-shore (from east and southeast) during autumn, winter, and spring, and generally on-shore (from southwest and northwest) during summer.

The mean high and low temperatures for January are 38°F and 28°F, respectively. Icing seldom occurs on the marine waters in the Sitka area.

The main input of fresh water to Sawmill Cove comes from the mill outfalls and Sawmill Creek. The average flow of wastewater from the pulp mill is estimated at 46 million gallons per day or 71 cubic feet per second (based on an estimated output of 600 tons per day). Sawmill Creek, from data for 1945 through 1950, had a yearly mean discharge of 481 cubic feet per second (cfs) with a maximum daily flow of 4860 cfs and a minimum of 34 cfs. The discharge of water from Sawmill Creek is partially dependent on pulp mill water use. Since the damming of Sawmill Creek to provide regulated flow from Blue Lake, flow data have not been obtained, and only a rough approximation of the present fresh water input to Sawmill Cove can be made. The daily input from the mill discharge and Sawmill Creek can be expected to vary between 4930 and 105 cfs, with a mean flow of 550 cfs. Watershed flow retention is moderate because of the heavy precipitation and a generally steep watershed gradient.

Oceanography

The fresh water input to Silver Bay mixes with saline waters and forms a very shallow surface layer of brackish water. Beneath this surface layer, horizontal and vertical salinity gradients are small and salinities are near oceanic values.

The temperature of the surface layer is determined by seasonal variations in air temperature and by the temperature and volume of fresh water input. Again, below the surface layer, horizontal and vertical temperature gradients are small and temperatures are near oceanic values.

Current measurements in Silver Bay in 1956 and 1957 showed that circulation patterns are determined by the amount of fresh water runoff, density differences between Silver Bay and Sitka Sound, wind stresses, and, to a lesser degree, tidal forces. (1) During high runoff, from June to October, the circulation pattern is of the classical fjord type, with a strong outflow in the shallow surface layer and with the inflow close below the surface layer. Silver Bay also has a sill, a fairly common feature of fjords. In July, 1956, at the entrance to Silver Bay, the surface layer was 6 meters thick, with a maximum outward current of 0.15 meters per second. The lower layer was 15 meters thick, with a maximum inflow of 0.05 meters per second. The lower 60 meters of water were essentially motionless. Strong west winds blow up the Bay and can reverse the surface currents for short periods of a few days, accruing surface water with its sulfite waste liquor up-bay from the pulp mill.

From January through April, runoff to Silver Bay is at a minimum. Winds are predominantly from the southeast, tending to drive the surface waters out of the bay towards Eastern Channel. At these times the dense oceanic water flows inward under the surface water and then

moves upward to replace the surface water driven outward by the wind. Inflow-outflow occurs throughout the entire depth of the bay in winter, in contrast to the spring and summer high flow period, when only the top one-third of the bay is affected. In March 1957 current measurements showed the surface layer to be 30 meters thick, with a maximum velocity of 1.10 meters per second. At the same time the bottom layer was 60 meters thick, with a maximum velocity of 0.02 meters per second.

Tidal forces are usually insufficient to cause the surface layer to flow into the bay during flood tide. In December 1956, however, when neither wind stress nor density differences were great, surface transport into Silver Bay was observed during a flood tide. (2)

Sulfite waste liquor, temperature, and salinity data obtained during a 1968-1970 study (3) agreed with the data of the 1956-1957 study (1). Pollutants in the surface waters of Silver Bay at Sawmill Cove are affected by wind conditions and the volume of fresh water entering the Bay. Normally, the wastes flow out of the Bay into Eastern Channel. An up-bay wind however, will drive high concentrations of sulfite waste liquor to the head of the Bay. On other occasions, when fresh water input is low (during winter months), upwelling, and thus vertical mixing, occurs in the upper reaches of the Bay.

Flushing times for Silver Bay, which indicate how long a conservative constituent will remain in the Bay, have been estimated from the data obtained in earlier studies. During low runoff, the flushing time was calculated to be 320 days, during high runoff, 87 days (3).

Water Uses

Fisheries resources in Silver Bay are an important asset to Southeastern Alaska and especially to the Sitka area (1). As indicated earlier, Silver Bay is an important wintering ground for herring and also serves as a nursery ground for young herring which either migrate into the bay or are spawned there. Tributaries entering Silver Bay support salmon runs and the bay serves the important functions of providing a nursery area for young salmon and a feeding ground for adult salmon. The discharge of sulfite waste liquor and other wastes into Silver Bay limits its uses for these purposes. Such wastes have had extremely serious consequences on the fisheries resources of the bay, i.e., the fish kills previously mentioned.

Silver Bay is very accessible and except for the Sawmill Cove area, is used for recreational fishing and boating by local residents. The bay offers aesthetically pleasing sites within a major scenic area of Alaska.

Previous Studies

A great variety of marine life was found in the inter and subtidal zones of Silver Bay prior to the discharge of wastewaters from the Alaska Lumber and Pulp Company (1). In many benthic reaches of the bay, marine life was scarce because of anaerobic bottom conditions in areas deeper than 27 meters, as indicated by odors of hydrogen sulfide gas. Of particular interest in the 1957 report is the almost complete absence of hydrogen sulfide and anaerobic conditions in Sawmill

Cove. During the same study, dissolved oxygen values throughout the surface waters of Silver Bay showed seasonal variations characteristic of clean waters. The values for surface waters ranged from 7.1 mg/l during the winter to 18.2 mg/l during the spring. At the 100-foot depth, dissolved oxygen varied from 6.9 to 12.9 mg/l.

Studies conducted in August 1965 revealed high SWL concentrations throughout the surface waters of Silver Bay (4). The threshold toxicity of sulfite waste liquor (50 mg/l) to important food chain organisms such as copepods, euphausids, mysids, and candlefish, was exceeded. Near-surface SWL values were greater than those found to cause 100 percent mortality of egg and larval stages of oysters and certain bottom fish.

Dissolved oxygen in Silver Bay in 1965 was less than the concentrations found during the 1956-1957 study. In 1965 dissolved oxygen values in surface layers ranged from 4 to 6 mg/l. Between 2 and 10 meters, dissolved oxygen values increased to 7 and 8 mg/l, but dissolved oxygen concentrations less than 6 mg/l were found in the mill outfall area. In August 1956, prior to the discharge of pulp mill wastes into Silver Bay, dissolved oxygen concentration ranged from 9.0 to 11.5 mg/l in the surface waters, from 8.5 to 11.0 mg/l at the 5 meter depth, and from 8.1 to 10.8 mg/l at the 30 meter depth. Degradation of surface waters, as shown by decreased dissolved oxygen concentration in 1965, was attributed to the biochemical oxygen demand of pulp mill wastes and to possible inhibition of phytoplanktonic oxygen production resulting from high concentrations of SWL.

A 1968-1970 study by the U.S. Environmental Protection Agency (3) revealed that the surface waters of an eleven square mile area were affected by sulfite waste liquor that ranged from 137 to over 3,000 mg/l at various times of the year. Of 385 samples collected during this study from the upper 20 meters of water at 34 stations, 68 percent had more than 10 mg/l of sulfite waste liquor, a level damaging to many immature forms of finfishes and shellfish. About 48 percent of these samples had sulfite waste liquor concentrations greater than 50 mg/l, about 29 percent had more than 200 mg/l, and 10 percent exceeded 400 mg/l.

During the same study, in the upper 10 meters of water, dissolved oxygen was found to be decreased only occasionally below 6.0 mg/l, the minimum value allowed by the Alaska Water Quality Standards criterion for this parameter (5). Such low dissolved oxygen levels were measured in August 1970, when mill wastes were expected to have the greatest influence on the waters of Silver Bay, because of prevailing oceanographic and meteorologic features (i.e. low stream discharge and precipitation, little wind, cool temperatures, etc.).

Of greater importance in the 1968-1970 study was the finding that much of Sawmill Cove and an adjacent reach of Silver Bay was covered with sludge that was characterized as consisting of significantly more than 5 percent organic carbon and more than 0.10 percent organic nitrogen. These sludges contained hydrogen sulfide, wood chips, and a readily recognizable mat of pulp fibers. The sludges from a chemical viewpoint were similar to raw wastes from domestic

sewage and to untreated packing house wastes. The benthic fauna in the area reflects the degraded condition of the sediments in that only a few highly pollution-tolerant polychaete worms were found in any of the sediment samples. Additionally, intertidal forms, especially the blue mussel Mytilus edulis, were reduced in numbers along a significant reach of northern shoreline adjacent to Sawmill Cove.

WATER QUALITY STANDARDS

The present Alaska Water Quality Standards (6) designate the marine waters of the state, including Sawmill Cove, Silver Bay, and Eastern Channel as Class C, D, E, and G. Beneficial uses of marine waters include water contact recreation, industrial water supply, growth and propagation of aquatic life and waterfowl, fur-bearers, and other water-associated life. The standards criteria associated with marine waters that are of particular interest in this report are those for dissolved oxygen, residues in the form of floating solids and sludge deposits, and toxic substances. Of the various classifications, Class D and E have the most stringent criteria:

Dissolved Oxygen

Class D - greater than 6 mg/l in salt water.

Class E - greater than 6 mg/l in the larvae state. Greater than 5 mg/l in the adult stage.

Residues

Class D - residues may not make the receiving water unfit or unsafe for the uses of this classification; nor cause a film or sheen upon, or discoloration of, the surface of the water or adjoining shoreline; nor cause a sludge or emulsion to be deposited beneath or upon the surface of the water, within the water column, on the bottom or upon adjoining shorelines. Residues shall be less than those levels which cause tainting problems as determined by bioassay.

Class E - same as Class D.

Toxic Substances

Class D - concentrations shall be less than those levels which cause tainting of fish, less than acute or chronic problem levels as revealed by bioassay or other appropriate methods and below concentrations affecting the ecological balance.

Class E - same as Class D.

SAMPLING PROGRAM

The sampling of the waters of Silver Bay and Eastern Channel was done while routine compliance monitoring surveys in the pulp mill were being conducted. The receiving water sampling was conducted to determine the improvements, if any, in water quality following installation and operation of the mill's primary treatment plant for pulp processing wastewaters. Sufficient data were available from previous studies to compare with the 1974 findings reported herein to assay the magnitude of any significant improvements in water quality as related to the Alaska Water Quality Standards.

Previous studies reveal that degradation of water quality occurred primarily in the top 10 meters of water. For this reason, and because it was believed that any gross improvements in water quality would first be apparent in these upper water reaches, the 1974 sampling program for dissolved oxygen, pH, temperature, conductivity and sulfite waste liquor was restricted to the top 12 meters of water in Silver Bay and Eastern Channel. The bottom deposits of Sawmill Cove were sampled for the same reasons also. Chemical tests for sulfides, percent volatile solds, total organic carbon, and total organic nitrogen, and visual inspections for macroscopic animal components were conducted on the samples from the bottom deposits. Their general composition also was noted.

Sampling Stations

A total of 34 stations were previously established as the study area in the 1968-1970 sampling program. During the 1974 sampling period, the sampling area remianed the same (Figure 2), but the number of stations was reduced to 23. Of these only 12 were intensively sampled, and they were the ones most closely associated with the mill discharges and Sawmill Cove. The same station numbers used in the 1968-1970 study were retained for easier reference with the September 1974 survey.

Sampling Periods

Although the seasonal variation in water quality of the study area had been evaluated in previous reports (1 and 3), such determinations were beyond the scope of the 1974 survey. Additionally, it was believed that any major improvements in water quality would be apparent during any sampling period other than winter or spring. Thus, only one survey was made, but the intensity of sampling during the 1974 survey was increased to offset anomalous situations that might occur because of tidal variations.

Except for Stations 3-5 for the September 18 sampling period,* sampling for the selected chemical and physical parameters was accomplished shortly after the onset of the beginning of a new tidal change, i.e., flood or ebb. Stations 6-8, 12-16, 20-22, and 35 include the reaches of Silver Bay that are most affected by wastewater discharges

*Boat motor malfunction precluded sampling these stations at the selected time.

from the pulp mill, and were sampled during two flooding tides and two ebbing tides. Stations 1-5, and 23-28 are quite distant from the discharges from the mill and were sampled only during one flood and one ebb tide just to verify whether sulfite waste liquor still occurs in these reaches of the Silver Bay - Eastern Channel System. The tidal data and the beginning and end of the sampling at all Stations, except Stations 3-5 on September 18, are as follows:

September 17, 1974

Time of Low Tide:	0904	Time of Beginning of Sampling:	1100
Time of Next High Tide:	1512	Time of Ending of Sampling:	1600
Time of High Tide:	1512	Time of Beginning of Sampling:	1600
Time of Next Low Tide:	2134	Time of Ending of Sampling:	1800

September 18, 1974

Time of Low Tide:	0943	Time of Beginning of Sampling:	0930
Time of Next High Tide:	1550	Time of Ending of Sampling:	1200
Time of High Tide:	1550	Time of Beginning of Sampling:	1600
Time of Next Low Tide:	2219	Time of Ending of Sampling:	1900

The sampling route was always along the shortest route in the numerical sequence of station numbers (i.e., from Station 6 through Station 22) during each tidal segment.

Methods

Dissolved oxygen, temperature, conductivity, and pH were determined with a Hydrolab Model 6D Surveyor Portable Water Monitor*

*Use of product and company names is for identification only and does not constitute endorsement by the U. S. Environmental Protection Agency

instrument that frequently was calibrated each sampling period, for example, the beginning and end of each sampling cycle. Additionally, the dissolved oxygen probe of this instrument was calibrated to the standard Winkler method each time a suspected erratic value for this parameter was obtained.

Salinity determinations were calculated from the conductivity and temperature data obtained with the Hydrolab instrument. Sulfite waste liquor samples were collected in cubitainers, and shipped via air freight in ice-packed containers to the U.S. Environmental Protection Agency laboratory in Seattle, Washington where SWL concentrations were measured using the Pearl-Benson Index method of analysis (8).

The pH probe of the Hydrolab instrument did not function properly throughout the course of the 1974 survey, so only a very limited amount of pH determinations were made.

Chemical analysis of the bottom deposit samples were made at the same laboratory facility. As with the SWL samples, the bottom deposit samples were packed in ice for preservation prior to air shipment. Bottom deposit samples were obtained by use of a small Petersen dredge. A small portion of each of these samples was collected for chemical analyses and the remainder was inspected for animal life subsequent to screening through a 30 mesh U.S. Standard Sieve. Visual inspections of these samples were made to determine the presence or absence of animal life and pulp fiber mats, and odors of the deposits were noted.

RESULTS AND DISCUSSION

Temperature and Salinity

Data from previous studies (1 and 4) show that Silver Bay was stratified with a lens of less-dense and poorly mixed brackish water that overlays subsurface and more saline and dense waters during the fall of the year. These conditions inhibit vertical mixing because of differences in density in these water layers and have an important bearing in the distribution of soluble pollutants discharged to the cove, that is, they are located primarily in the surface waters above the 10 meter depth even though the cove generally is much deeper.

As in the previous studies, similar density patterns were found during the present sampling period. The more saline, cooler, and therefore denser water is located beneath less saline, warmer, and lighter upper layers. This pattern is so predominant throughout the study area that it can be readily observed in just the temperature and salinity data collected throughout the course of this survey (Appendix Table 1A and 2A) and is the result of the discharges of non-brackish waters from Sawmill Creek, other tributaries, and from the Alaska Lumber and Pulp Company which in the fall at least are less dense, less saline, and generally warmer than the highly saline marine waters deeper in the bay and in Eastern Channel. This pattern also is typical of many other estuaries throughout Southeastern Alaska.

Sulfite Waste Liquor

The importance of the above pattern of density and stratification in the waters of Silver Bay and the adjacent reaches of Eastern Channel is that the majority of the soluble pollutants (mostly sulfite waste liquors discharged from the primary treatment plant) are distributed in the uppermost water layers above a depth of 10 meters, as was found in previous studies (3 and 4) and during the September 1974 survey (Table 1).

The Alaska Lumber and Pulp Company, in compliance with one of the conditions of its waste discharge permit issued in 1971 by the Alaska Department of Environmental Conservation, has been collecting sulfite waste liquor data from several stations in Silver Bay and Sawmill Cove. SWL data from September 1972 for several of these stations (Stations 12, 13, 14, 15, and 16) were selected for comparison with corresponding stations sampled during September 1974, and show reasonable agreement (Table 2), and also are in reasonable agreement with the data for the 1968-1970 study (Appendix Table 3A).* These sets of data reveal no major change in sulfite waste liquor concentrations at the 1 and 5 meter depths during the past few years. Additionally, there has been no major change in pulp mill production for the same period, thus there is no basis for SWL concentration to change significantly during these times.

*Data from the August 1965 survey, although not recorded herein, generally are quite similar to the 1968-1970 findings for SWL at the surface, 2 meter and 5 meter depths at corresponding stations.

TABLE 1

SULFITE WASTE LIQUOR CONCENTRATIONS (MG/L)
WITH DEPTH IN METERS IN SILVER BAY AND ADJACENT WATERS
SEPTEMBER 17, 1974 1100 - 1600 HOURS

	STATION NUMBERS																					
	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
DEPTH																							
1	19	28	29	33	42	20	38	43	196	64	46	33	51	11	34	39	59	158	157	117	105	110	43
5	21	16	14	5	8	11	20	15	13	13	18	25	21	6	11	10	2	7	43	11	48	10	13
10	-	-	-	-	-	2	15	6	1	2	16	4	5	3	6	5	-	-	-	-	-	-	3
12	-	-	-	-	-	3	20	5	1	2	2	4	2	2	4	8	-	-	-	-	-	-	3

TABLE 1 (CONTINUED)

SULFITE WASTE LIQUOR CONCENTRATIONS (MG/L)
WITH DEPTH IN METERS IN SILVER BAY AND ADJACENT WATERS
SEPTEMBER 17, 1974 1600 - 1800 HOURS

	STATION NUMBERS																						
	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
DEPTH																							
1	-	-	-	-	-	22	64	45	620	146	18	720	270	14	635	42	-	-	-	-	-	-	123
5	-	-	-	-	-	15	16	15	9	9	14	18	18	4	55	8	-	-	-	-	-	-	18
10	-	-	-	-	-	6	7	-	4	2	2	19	2	3	6	2	-	-	-	-	-	-	6
12	-	-	-	-	-	6	1	-	5	3	4	6	3	1	4	1	-	-	-	-	-	-	3

TABLE 1 (CONTINUED)

SULFITE WASTE LIQUOR CONCENTRATIONS (MG/L)
WITH DEPTH IN METERS IN SILVER BAY AND ADJACENT WATERS
SEPTEMBER 18, 1974 0930 - 1200 HOURS*

	STATION NUMBERS																						
	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
DEPTH																							
1	-	-	22	32	21	27	37	44	380	60	29	504	103	19	53	81	96	273	107	118	112	129	58
5	-	-	9	18	8	5	11	11	5	24	4	5	11	47	11	48	11	41	30	12	44	36	27
10	-	-	-	-	-	2	5	6	4	4	5	2	2	4	2	7	-	-	-	-	-	-	3
12	-	-	-	-	-	3	7	6	2	5	1	4	4	2	2	5	-	-	-	-	-	-	5

*The sampling at Stations 3-5 was accomplished from 1530 to 1630 hours instead of the period from 0930 to 1200 hours. The desired time was the period from 0930 to 1200 hours but could not be accomplished because of a faulty boat motor.

TABLE 1 (CONTINUED)

SULFITE WASTE LIQUOR CONCENTRATIONS (MG/L)
WITH DEPTH IN METERS IN SILVER BAY AND ADJACENT WATERS
SEPTEMBER 18, 1974 1600 - 1900 HOURS

	STATION NUMBERS																					
	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
DEPTH																							
1	-	-	-	-	-	-	21	20	69	51	6	556	85	14	77	185	-	-	-	-	-	-	35
5	-	-	-	-	-	-	15	14	8	11	6	24	10	31	9	10	-	-	-	-	-	-	7
10	-	-	-	-	-	-5	6	8	2	4	3	6	5	5	4	6	-	-	-	-	-	-	3
12	-	-	-	-	-	5	4	8	4	3	3	16	6	4	2	6	-	-	-	-	-	-	4

TABLE 2

MINIMA, MAXIMA, RANGE, AND AVERAGE SULFITE WASTE LIQUOR (SWL) CONCENTRATIONS DURING SEPTEMBER 1972 AND 1974 (RESPECTIVELY BEFORE AND AFTER INSTALLATION OF PRIMARY TREATMENT) AT STATIONS 12 THROUGH 16 IN SILVER BAY, BASED ON DATA FROM ALASKA LUMBER AND PULP COMPANY.

	1 METER DEPTH				5 METER DEPTH		
STATION NUMBER	MINIMUM SWL CONC.	MAXIMUM SWL CONC.	AVERAGE SWL CONCENTRATION		MINIMUM SWL CONC.	MAXIMUM SWL CONC.	AVERAGE SWL CONCENTRATION
				SEPTEMBER 1974			
12	29	542	297		0	73	18
13	40	135	85		0	44	19
14	27	728	241		4	20	13
15	44	864	430		9	135	49
16	35	892	462		4	73	37
				SEPTEMBER 1972			
12	64	477	245		5	44	19
13	58	892	304		9	309	71
14	5	104	61		5	11	8
15	64	1110	344		11	31	20
16	46	1638	390		7	67	31

Of 232 samples taken at 23 stations at the 1, 5, 10, and 12 meter depths during the 1974 sampling period, 14 percent (33 samples) had SWL concentrations greater than 50 mg/1, and 51 percent (119 samples) had more than 10 mg/1 (Table 1). Sulfite waste liquor at 50 mg/1 has been shown to be toxic to phytoplankton and salmon fish-food organisms, and magnesium oxide base waste liquor at 10 ppm has been shown to be damaging to some forms of immature (larval) shellfish (8 and 9).

A total of 189 samples were collected at all stations above a depth of 12 meters. Of these, 62 percent (117 samples) had sulfite waste liquor concentrations of 10 or more mg/1. In the main reach of Silver Bay most affected by mill discharges, and where intensive sampling was accomplished (Stations 6-8, 12-16, and 20-22), a total of 192 samples were taken at 1, 5, 10, and 12 meters, and calculations reveal that sulfite waste liquor concentrations of 50 or more and 10 or more mg/1 were respectively present in this water mass in 12 and 46 percents of the samples. At the 1 and 5 meter depths, 10 or more mg/1 of sulfite waste liquor were found in 86 percent of the 134 samples collected throughout the entire 11 square mile study area. Sulfite waste liquor at values of 50 or more mg/1 is particularly noticeable in the layer of water at the 1 meter depth. At this depth during the 1968-1970 study (Appendix Table 3A) SWL concentrations, with some exceptions, were within the same magnitude of concentrations as were those found during the September 1974 survey (these exceptions being Station 16 in the 1968-1970 study where the sulfite waste liquor

concentrations were substantially higher during July 24, 1968, April 22 or 23, 1969, and August 20, 1970, at either the surface or 1 meter depths*). Thus, the great similarities found in the sulfite waste liquor concentrations during the three surveys, and monitoring studies by the mill during 1973-1974, indicate that no major reduction of sulfite waste liquor has been achieved in Silver Bay or Eastern Channel since the installation and operation of the mill's primary treatment system for pulp processing wastewaters in late 1972. This is to be expected, however, because the primary treatment system is designed for removal of settleable solids pollutants rather than dissolved pollutants such as sulfite waste liquor.

Of particular interest in the September 1974 survey are the sulfite waste liquor concentrations at the one meter depths. None of these values exceeded 75 mg/l at Stations 1-8, 14, and 20, whereas in the one meter depth, values at all other Stations at one time or another were substantially greater than 75 mg/l. This feature indicates that during the September 17 and 18, 1974 survey, most of the sulfite waste liquor is to be found seaward of the reach from Herring Cove and in the central and northern part of Eastern Channel rather than in the upper areas of Silver Bay beyond Herring Cove. This in turn is suggestive of net displacement of surface waters downbay and is the result of freshwater discharges entering the bay rather than

* There is no readily apparent reason for the higher SWL values at Station 16 during the 1968-1970 study. It is suggested, however, that they are the consequence of local anomolous conditions brought about by currents, wind, and/or precipitation.

tidal or non-tidal currents within the system.*

The finding of sulfite waste liquor in the near surface and surface waters of upper reaches of Silver Bay (Station 1-5) during flooding tides on September 17 and 18, 1974, and at both flooding and ebbing tides at other times during the months of March, April, October, and December in the 1968-1970 survey, and during ebbing tides during the 1965 study period is of more than rare occurrence, and is suggestive that tidal currents are weak. This supports the study findings on surface currents prior to operation of the mill. Wind apparently influences the surface currents and subsequent distribution of sulfite waste liquor in the upper reaches of the bay as a result of the weak tidal currents, because data obtained on one day when the tide was ebbing while a strong wind was blowing upbay showed significant concentrations of sulfite waste liquor (10 or more mg/l) in the upper bay reaches (3). Thus, significant concentrations of sulfite waste liquor can be found throughout the surface and near surface waters of the entire 11 square mile study area much of the time, and the distribution of sulfite waste liquor is a function of weak tidal and non-tidal currents, direction and strength of winds, time of day regarding tidal stage, and density of the water in the study area.

*The 1957 report (1) states that studies of currents in the upper 14 feet of water are weak and variable in both direction and speed. Neither tidal or non-tidal currents are strong enough or regular enough to provide good flushing of bay.

Dissolved Oxygen

During May 16, 1956, prior to construction of the pulp mill, dissolved oxygen at Point Bucko (adjacent to Station 16) ranged from about 8.7 mg/l near the surface (2 meter depth) to about 8.2 mg/l at 10 meters (1). Upbay near Bear Cove at Station 4, dissolved oxygen varied from 10 mg/l near the surface to about 8.3 mg/l at 10 meters. Later in the same year, September 11, dissolved oxygen at Station 16 ranged from 10.0 mg/l near the surface to 9.1 mg/l at 4.6 meters, and at Station 4 at corresponding depths it varied from 9.4 to 9.6 mg/l. Elsewhere in the entire survey area throughout the course of this study, dissolved oxygen ranged from 8.3 to 14.2 mg/l near the surface and from 8.2 to 13.9 mg/l at 4.6 meters.

In an August 1965 study, six years after installation of the pulp mill, dissolved oxygen at the surface varied from 4.4 to 6.1 mg/l at Stations 4, 6-8, 13-16, 20-22, 25, and 36 (4). At stations 13-16 and 36, those nearest the pulp mill outfalls, the dissolved oxygen in the surface waters ranged from 5.1 to 7.0 mg/l. Similar degradation at the same stations nearest the mill outfalls was evident at the 2 meter depth, too, where dissolved oxygen ranged from 7.1 to 7.7 mg/l. During the same survey, sulfite waste liquor concentrations at the surface ranged from 15 to 137 mg/l at Stations 13-16 and 36, and at the 2 meter depth at the same stations, it varied from 3 to 43 mg/l. A subsequent study during the 1968-1970 study revealed similarly depressed dissolved oxygen concentrations in the upper 5

meters of water, and these corresponded with similarly high, and higher, concentrations of sulfite waste liquor that, at times, amounted to, and infrequently greatly exceeded, 430 mg/l at the stations closest to the mill outfalls.

As is the case for sulfite waste liquor, the Alaska Lumber and Pulp Company has also been collecting dissolved oxygen data from several stations in Silver Bay and Sawmill Cove for several years. These data at the 1 and 5 meter depths for Stations 12-16 (Silver Bay Stations closest to the Mill's main sewer) for the period of July, August, and September, 1972, prior to installation of the primary treatment facility, were compared with corresponding dissolved oxygen concentrations during the same period in 1974, about two years following installation and operation of the primary treatment facility (Figures 3 and 4, and Appendix Table 4A). This comparison* reveals that the primary treatment facility has resulted in a perceptible and significant, but incomplete, improvement in the dissolved oxygen concentrations in Silver Bay at both the 1 and 5 meter depths. The comparison also shows, however, that dissolved oxygen at these stations still is to be found at concentrations less than 6.0 mg/l standards criteria at these stations, but not at the 5-meter depths. The occurrence of dissolved oxygen at less than 6.0

*A similar comparison for the same period in 1973 could not be made because the pulp mill was not operating as a result of a labor strike which closed the mill from July 12 to September 27, 1973. This period of July-September is one of the most critical regarding dissolved oxygen.

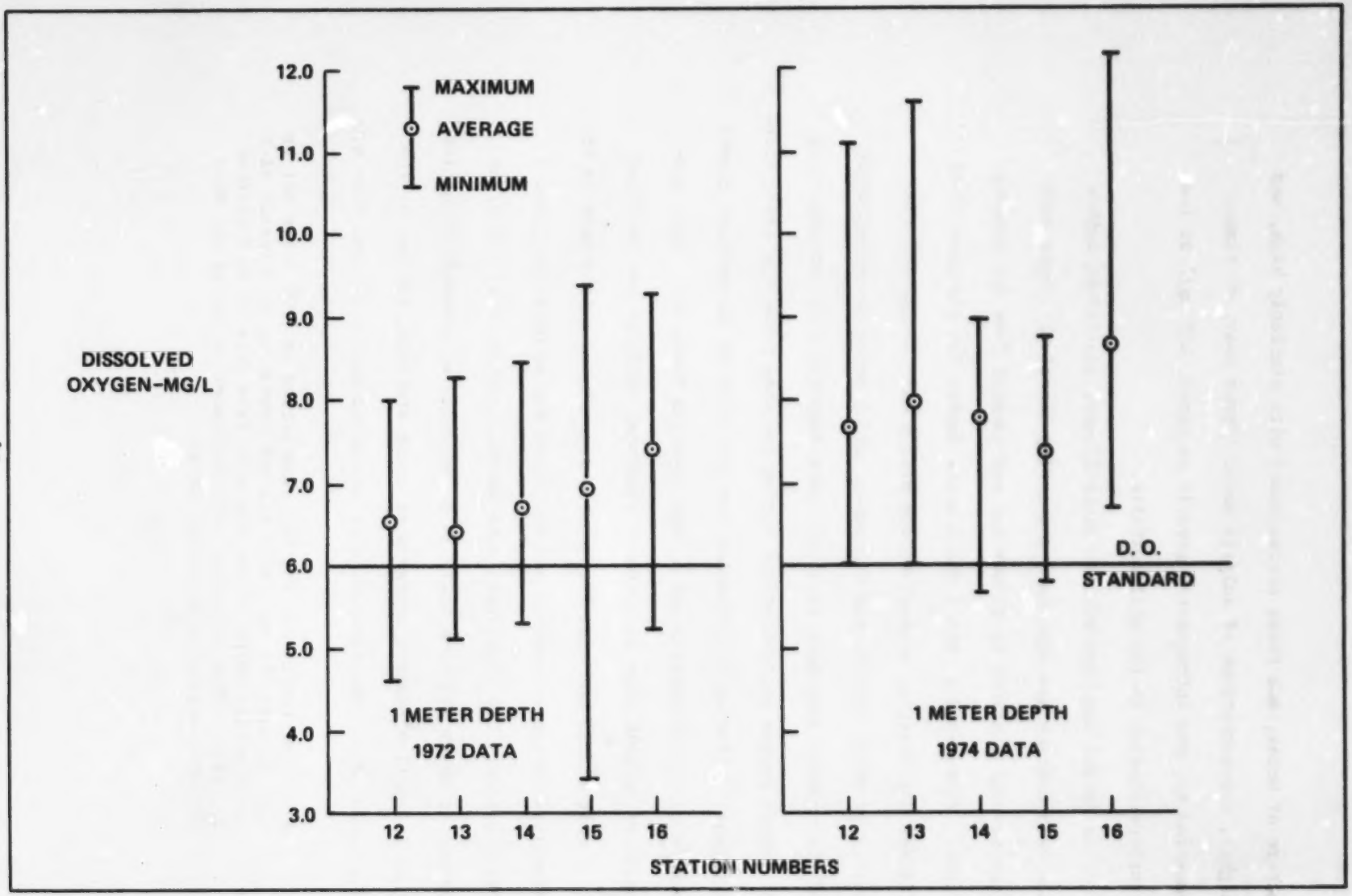

FIGURE 3. MAXIMA, MINIMA, RANGE AND AVERAGE DISSOLVED OXYGEN CONCENTRATIONS (MG/L) AT THE ONE METER DEPTH AT STATIONS 12 - 16 IN SILVER BAY DURING JULY, AUGUST AND SEPTEMBER BEFORE AND AFTER INSTALLATION OF PRIMARY TREATMENT FACILITIES AT ALASKA LUMBER AND PULP COMPANY, 1972 AND 1974.

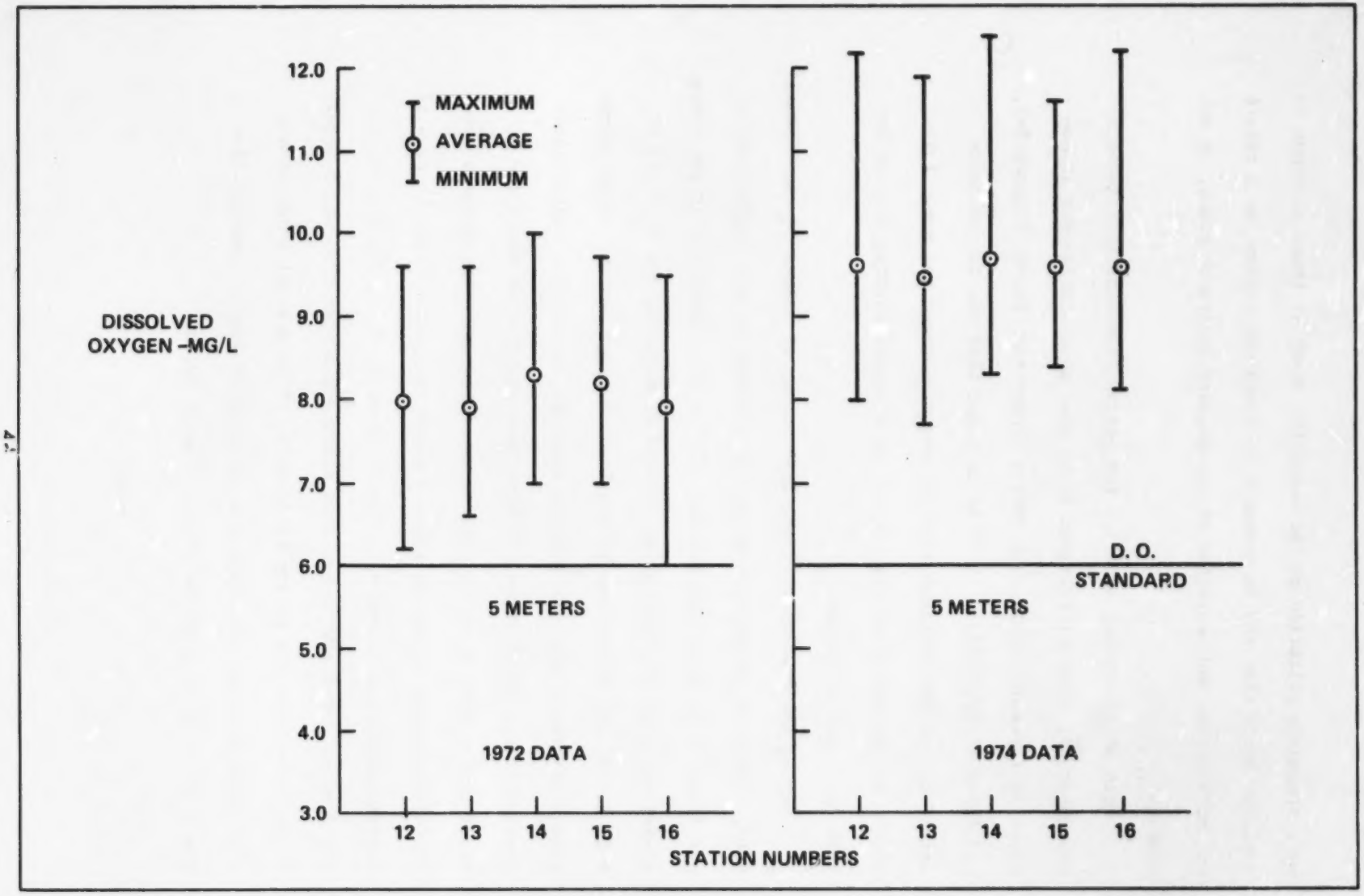

FIGURE 4. MAXIMA, MINIMA, RANGE AND AVERAGE DISSOLVED OXYGEN CONCENTRATIONS (MG/L) AT THE FIVE METER DEPTH AT STATIONS 12 - 16 IN SILVER BAY DURING JULY, AUGUST AND SEPTEMBER BEFORE AND AFTER INSTALLATION OF PRIMARY TREATMENT.

mg/l standards criterion at the one-meter depth at these stations is ample evidence that the improvement in dissolved oxygen, as a result of installation and operation of the primary treatment plant, is not complete.

Pulp mill sampling data for the period from June 1972 through September 20, 1974 for Stations 12-16 also show similar but incomplete improvement trends, but over a longer time frame (Figures 5-9, and Appendix Table 5A). It is to be noted that the improvements extend beyond the critical times of the mid-summer and early fall months to the period of high runoff in streams entering the bay in late April and early May.

During the September 17-18, 1974 survey of Silver Bay and Sawmill Cove, dissolved oxygen throughout all stations at all depths sampled was found to be more than 6.0 mg/l (Table 3). Dissolved oxygen almost always was more abundant at the 10 and 12 meter depths at Stations 6-8, 12-16, and 20-22 than at the 1 and 5 meter depths. This corresponds inversely with the general findings for sulfite waste liquor concentrations which typically were more abundant at the 1 and 5 meter depths than at the 10 and 12 meter depths. Inspection of the dissolved oxygen values in Table 3 shows that, except in six sets of determinations, i.e. one each for stations 3, 4, 7, 12, 20, and 21, the 1 meter depth always had more dissolved oxygen than the 5 meter depth throughout the entire study area. This general relationship also is associated with higher sulfite waste liquor concentration at the 1 meter depth compared to the 5 meter depth.

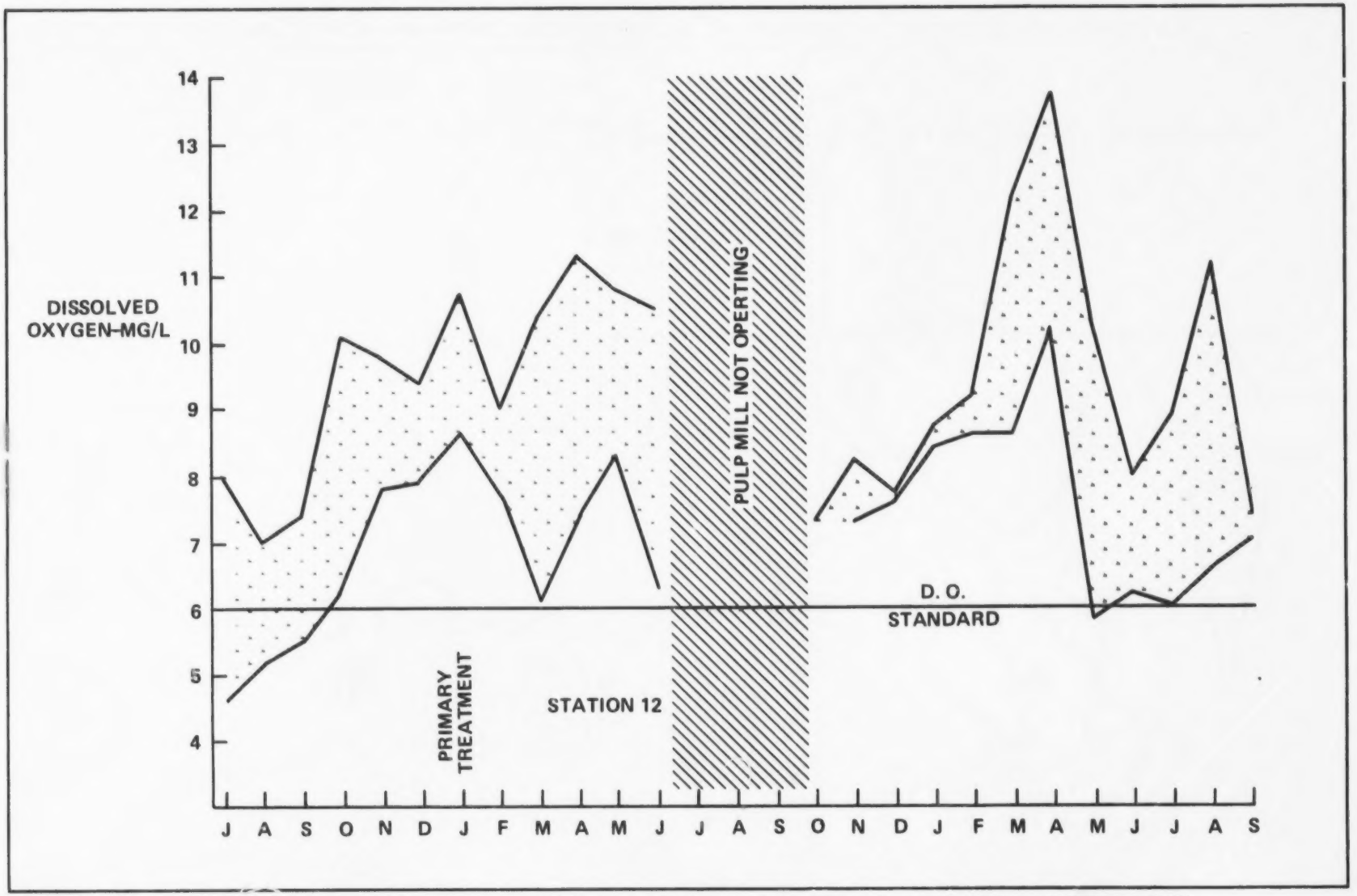

FIGURE 5. MONTHLY RANGE IN DISSOLVED OXYGEN (MG/L) AT STATION 12 IN SILVER BAY, JULY 1972 - SEPTEMBER 1974.

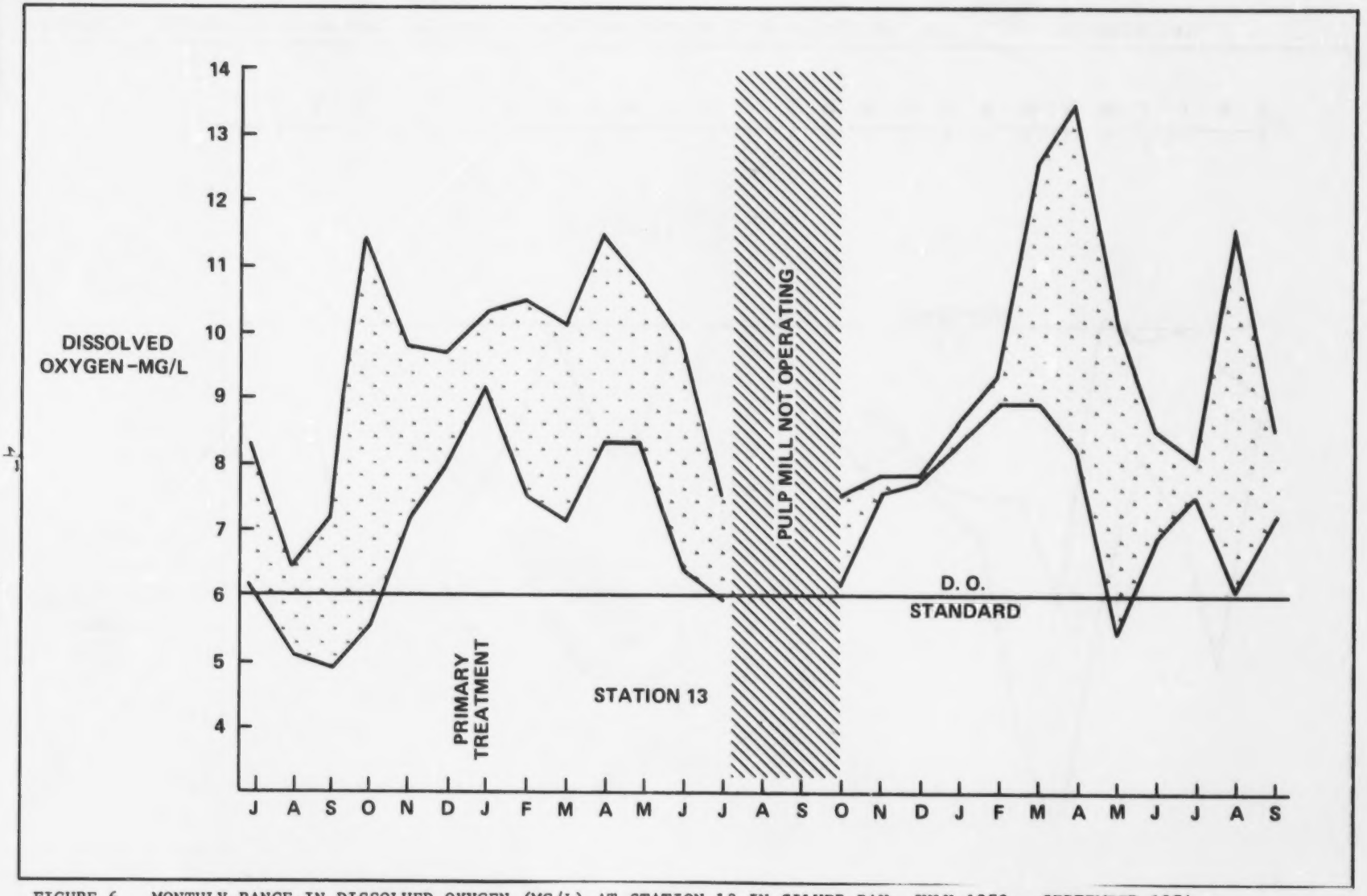

FIGURE 6. MONTHLY RANGE IN DISSOLVED OXYGEN (MG/L) AT STATION 13 IN SILVER BAY, JULY 1972 - SEPTEMBER 1974.

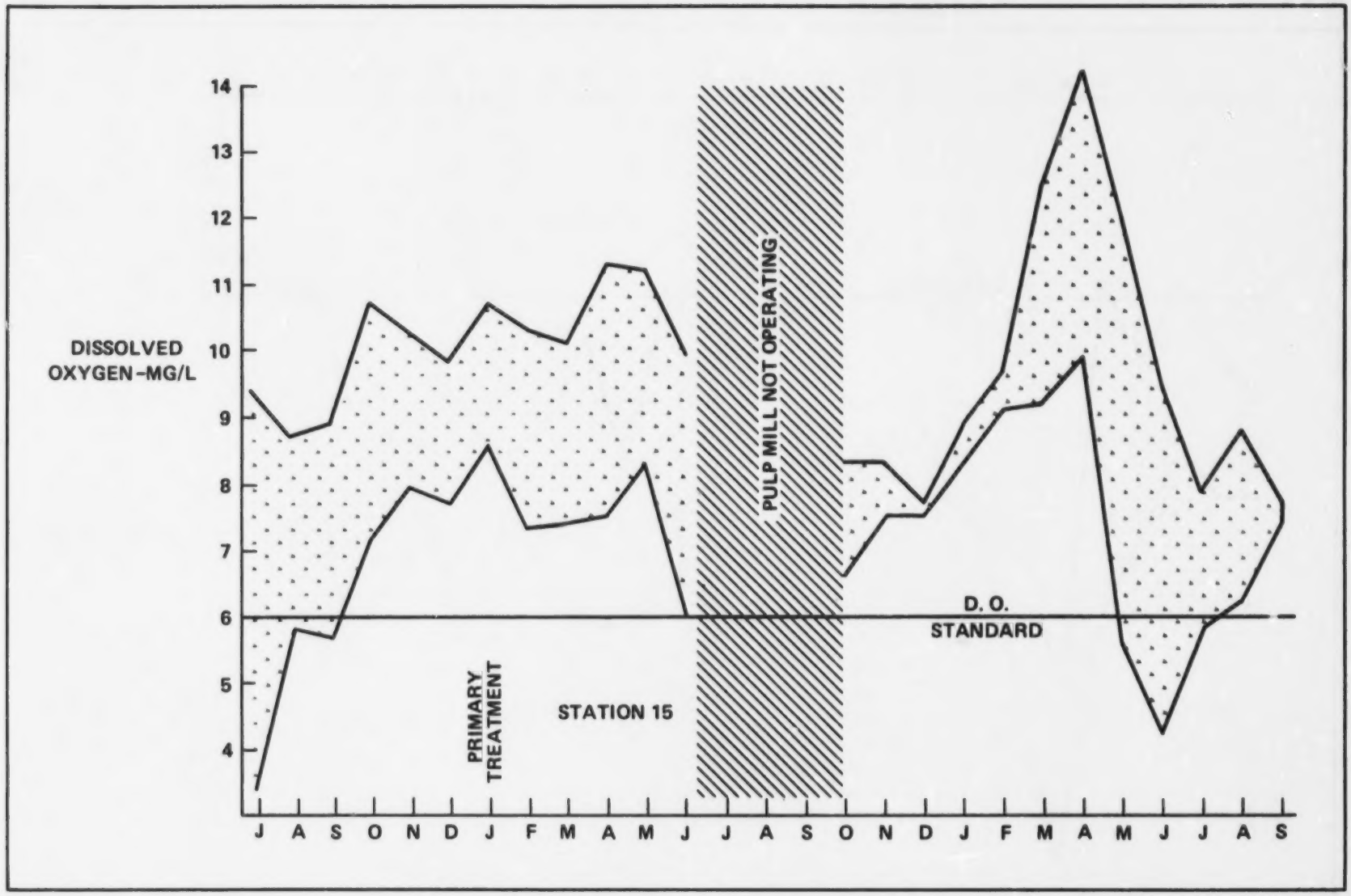

FIGURE 8. DISSOLVED OXYGEN AT STATION 15 IN SILVER BAY, JULY 1972 - SEPTEMBER 1974.

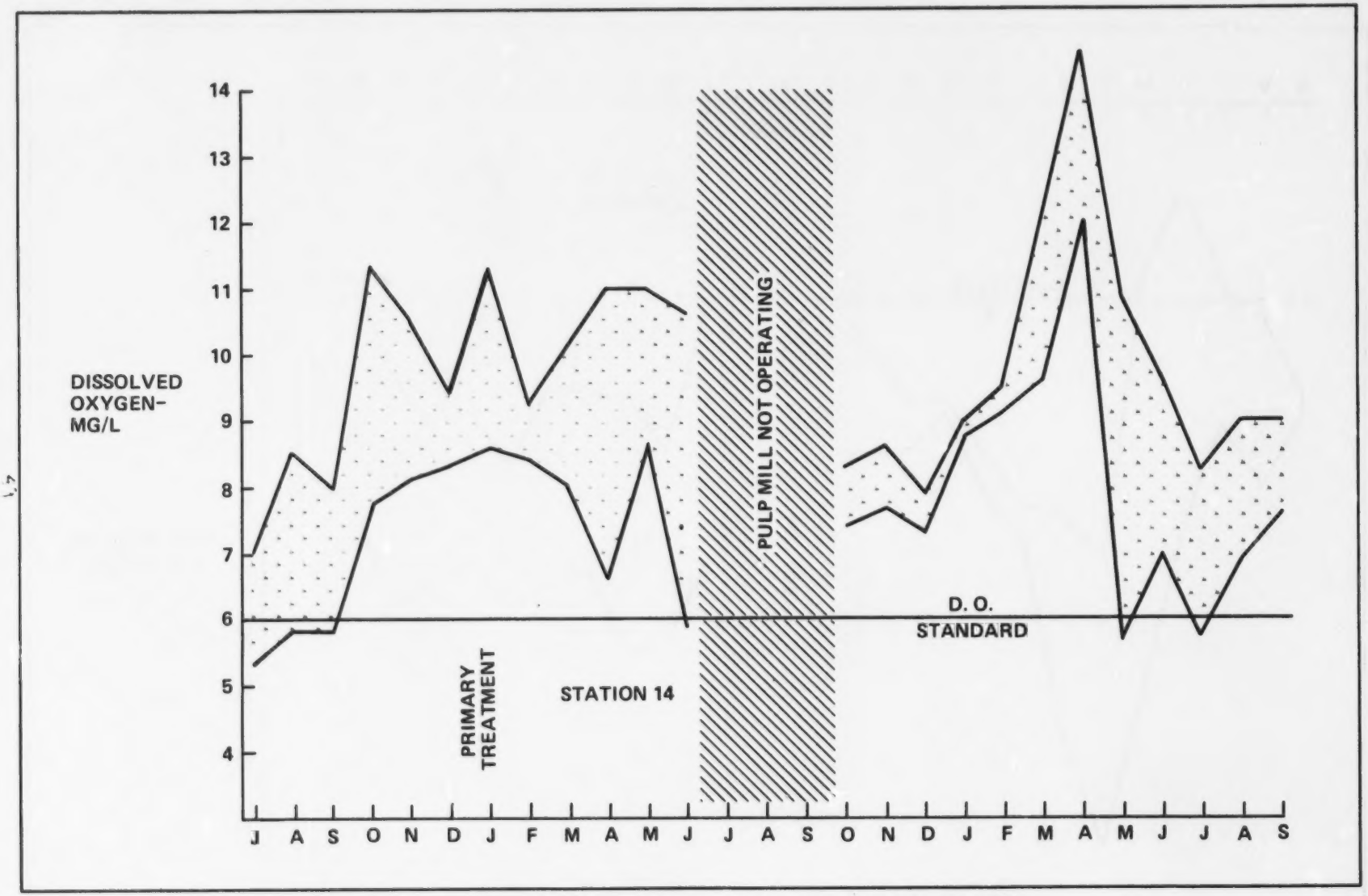

FIGURE 7. DISSOLVED OXYGEN (MG/L) AT STATION 14 IN SILVER BAY, JULY 1972 - SEPTEMBER 1974.

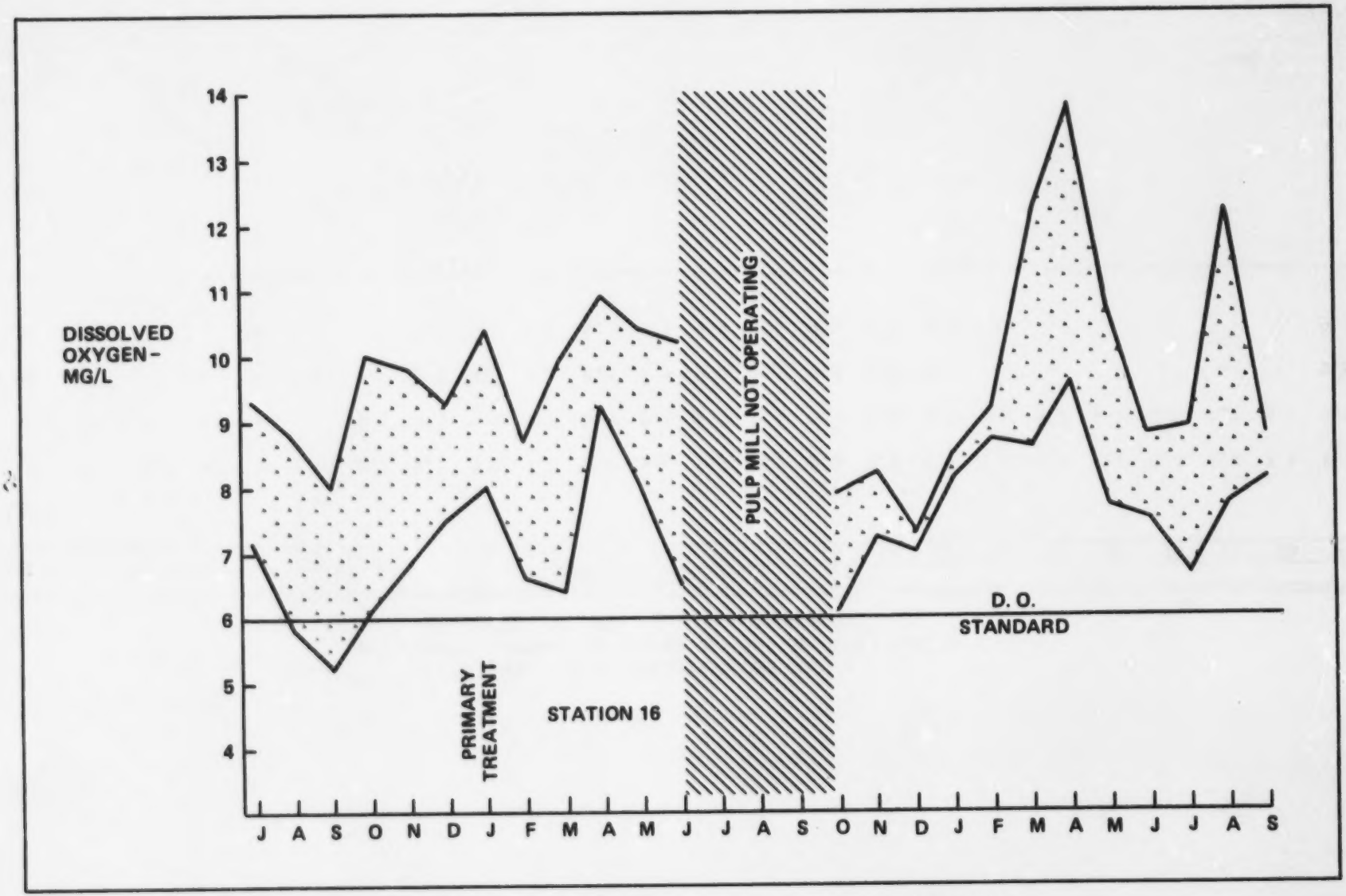

FIGURE 9. DISSOLVED OXYGEN (MG/L) AT STATION 16 IN SILVER BAY, JULY 1972 - SEPTEMBER 1974.

TABLE 3

DISSOLVED OXYGEN CONCENTRATIONS (MG/L)
WITH DEPTH (METERS) IN SILVER BAY AND ADJACENT WATERS
SEPTEMBER 17, 1974 1030 - 1600 HOURS

	STATION NUMBERS																					
	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	3
DEPTH																							
1	-	-	-	-	-	8.7	8.1	8.3	7.6	8.0	8.4	8.7	9.2	9.4	9.0	8.7	8.1	6.9	7.2	6.4	6.9	7.1	8.1
5	-	-	-	-	-	9.2	8.3	9.0	8.6	9.0	9.4	9.2	9.4	9.7	9.5	9.5	9.0	8.6	8.7	8.7	7.7	8.6	9.5
10	-	-	-	-	-	9.5	9.2	9.3	9.4	9.5	9.7	9.4	9.5	9.8	9.7	9.6	-	-	-	-	-	-	9.6
12	-	-	-	-	-	9.8	9.2	9.5	9.4	9.7	9.7	9.6	9.4	9.9	9.7	9.5	-	-	-	-	-	-	9.1

TABLE 3 (CONTINUED)

DISSOLVED OXYGEN CONCENTRATIONS (MG/L)
WITH DEPTH (METERS) IN SILVER BAY AND ADJACENT WATERS
SEPTEMBER 17, 1974 1600 - 1800 HOURS

	STATION NUMBERS																					
	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
DEPTH																							
1	-	-	-	-	-	8.6	7.6	7.9	8.5	8.6	9.2	8.4	8.9	9.7	8.9	8.8	-	-	-	-	-	-	8.5
5	-	-	-	-	-	8.9	8.7	8.6	8.9	9.3	9.6	8.8	9.1	9.2	9.3	9.4	-	-	-	-	-	-	9.1
10	-	-	-	-	-	9.2	9.4	8.2	9.3	9.5	9.8	9.5	9.3	9.7	9.3	9.5	-	-	-	-	-	-	9.2
12	-	-	-	-	-	9.2	9.6	9.2	9.6	10.0	10.0	9.7	9.4	9.7	8.9	9.6	-	-	-	-	-	-	9.3

TABLE 3 (CONTINUED)

DISSOLVED OXYGEN CONCENTRATIONS (MG/L)
WITH DEPTH (METERS) IN SILVER BAY AND ADJACENT WATERS
SEPTEMBER 18, 1974 0930 - 1200 HOURS

	STATION NUMBERS																					
	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	3.6
DEPTH																							
1	-	-	-	-	-	8.8	9.6	8.1	8.2	8.2	8.9	8.7	8.0	8.5	8.7	8.6	7.5	7.0	7.4	6.9	7.4	7.4	8.1
5	-	-	-	-	-	9.3	9.3	8.8	9.1	8.7	9.5	9.2	9.0	9.0	9.3	9.0	9.0	8.1	8.5	8.9	7.9	8.6	8.8
10	-	-	-	-	-	9.8	9.1	9.1	9.5	9.7	9.7	9.8	9.3	9.3	9.5	9.1	-	-	-	-	-	-	9.0
12	-	-	-	-	-	9.8	9.3	9.3	9.7	9.6	9.8	9.8	9.5	9.6	9.6	9.8	-	-	-	-	-	-	9.1

TABLE 3 (CONTINUED)

DISSOLVED OXYGEN CONCENTRATIONS (MG/L)
WITH DEPTH (METERS) IN SILVER BAY AND ADJACENT WATERS
SEPTEMBER 18, 1974 1500 - 1830 HOURS

	STATION NUMBERS																						
	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
DEPTH																							
1	-	-	8.6	8.0	9.2	8.7	9.2	9.1	9.8	8.7	9.0	8.6	9.2	9.0	8.1	8.5	-	-	-	-	-	-	8.3
5	-	-	8.6	9.0	9.0	9.1	9.6	9.3	7.9	9.4	9.3	9.2	9.6	9.5	8.9	9.1	-	-	-	-	-	-	9.2
10	-	-	-	-	-	9.2	9.5	9.4	8.9	9.7	9.6	8.6	9.3	9.5	9.2	9.5	-	-	-	-	-	-	9.3
12	-	-	-	-	-	9.3	9.6	9.6	9.6	9.9	9.7	8.5	9.6	9.5	9.5	9.5	-	-	-	-	-	-	9.3

pH

A total of 231 pH measurements were made throughout the study area, and all but 13 or 6% were within the range of the 7.5 to 8.5 criterion prescribed for class D and E waters by the Alaska Water Quality Standards (6). Seven of these 13 were both more than and less than the upper and lower limit at the upper end of Silver Bay (Stations 1 and 3-5), and one was above the upper limit at Station 23 which also had two values below the lower limit. Stations 12 and 16 each had one pH value less than the lower limit, but only 25 percent of the time (Appendix Table 6A).

The pH values greater than the upper limit of 8.5 are most probably the result of photosynthetic activity in the upper reaches of Silver Bay where attached marine plants thrive in great abundance in both the intertidal and subtidal zones of the bay. A moderate to rapid rate of phytosynthesis withdraws carbon dioxide from the water. When this occurs, there is a decrease in the acidity of the environment which appears as an elevated pH value or more alkaline conditions (carbon dioxide is a weak acid).

The pH values less than the lower limit of 7.5 is caused by the discharge of highly acidic wastewaters from the pulp mill which had an average pH near 4.0. Thus, it is evident that the discharge of low pH wastewaters from the mill had resulted in six violations of the pH criterion for water quality. All but one of these were in

downbay reaches from the pulp mill discharges in Sawmill Cove, the exception being at Station 12 which is influenced by these discharges in other ways also (i.e. significantly high sulfite waste liquor concontrations), as are most other stations in the Silver Bay-Eastern Channel System.

Unfortunately, there is a paucity of other pH data gathered from the study area in previous studies by regulatory agencies. The one study with the most pH data, the 1965 study (4) reveals, however, that pH values less than 7.5 were common in August and were found in surface waters at 8 of the 13 stations sampled. Each of these stations also had significant quantities of sulfite waste liquor. Thus, on the basis of this comparison, it is concluded that no major improvements have occurred in the pH of the waters of Silver Bay for several years. The finding of low pH values in the September 1974 survey is not unexpected, however, because the primary treatment facilities for pulp processing wastewaters installed by the mill in 1972 are not designed to decrease the acidity of these wastes and the mill, therefore, still discharges large volumes of highly acid wastes to Sawmill Cove and relies on dilution to neutralize the discharges.

Transparency

Of the 36 Secchi disk readings made in Silver Bay and Sawmill Cove (Table 4), none were less than the 1 meter criteria established in the Alaska Water Quality Standards. Such measurements have been

TABLE 4

SECCHI DISK (20CM) VISIBILITY IN METERS FOR SILVER BAY AND SAWMILL COVE

SEPTEMBER, 1974

STATION NUMBER	6	7	8	12	13	14	15	16	20	21	22	36
				SEPTEMBER 17, 1974		1100 - 1400 HOURS						
	6.96	7.06	7.62	3.83	2.54	8.22	2.08	1.50	7.03	4.70	5.92	2.18
				SEPTEMBER 17, 1974		1600 - 1800 HOURS						
	7.77	4.65	6.35	2.84	3.89	8.22	1.17	1.14	9.27	6.55	3.66	5.84
				SEPTEMBER 18, 1974		1000 - 1200 HOURS						
	7.59	5.97	9.39	3.61	1.21	6.02	2.11	1.12	4.85	3.91	3.56	2.87

reported in past surveys by regulatory agencies only one time (4). These show that the 1-meter standards criterion were not exceeded at this time either, but like the 1974 data, were close to this criterion at one location (Station 16). In the 1974 data, it is interesting to note, however, that the transparency criteria of not less than 1 meter was just barely met at Station 16, the sampling location closest to the pulp mill's main outfall. On this basis, no major changes have occurred in transparency since installation of the primary treatment facility. Stations 13 and 15 also had low readings.

Secchi disk readings of 10 meters would not be uncommon in unpolluted waters in coastal Southeastern Alaska waters during periods when plankton blooms are not apparent. It is to be noted that the 10 meter value is also approximated at Stations 8, 14, and 20 in Silver Bay while sulfite waste liquor concentrations were always significantly less than 50 mg/1.

Chemical and Physical Aspects of Bottom Deposits

Prior to the operation of the Alaska Lumber and Pulp Mill, the bottom deposits in Sawmill Cove consisted of course to silt size particles, pebbles and silt, and at one site adjacent to the present main sewer discharge, a heterogeneous mixture of a variety of materials and sawdust. A location near the mouth of Sawmill Creek had wood fibers, sand and mud (1). This site now is buried by a dugway fill which diverts Sawmill Creek to the eastern side of Sawmill Cove.

No subsequent sampling for bottom deposits in Sawmill Cove was accomplished until the 1968-1970 study (3). Such sampling during this study revealed the presence of a large and deep layer of sludge containing pulp fibers that extended over a 0.2 square mile reach of the bottom of much of Sawmill Cove and into the adjacent northwestern and seaward portion of Silver Bay to a point about midway between Stations 15 and 22 (Figure 10).

Chemical analyses of three sludge samples dredged from three stations in the uppermost reach of Sawmill Cove provided the following data:

Station Number	Total Organic Carbon (%, Dry Weight Basis)	Total Organic Nitrogen (%, Dry Weight Basis)
34	40.3	0.52
35	30.4	0.66
38	26.9	0.39

Marine deposits not influenced by wastewater discharges containing organic settleable solids are commonly characterized on a dry weight basis as consisting of less than 5 percent organic carbon and volatile solids and less than 0.10 percent of organic nitrogen and sulfides. From inspection of the above data and observations of the other bottom deposit samples collected during the 1968-1970 study, it was concluded that because the criteria for concentrations of organic carbon and organic nitrogen were greatly exceeded, the bottom of most of Sawmill Cove and an adjacent reach of Silver Bay were grossly polluted.

Sampling of the Sawmill Cove deposits in 1974 and those in the

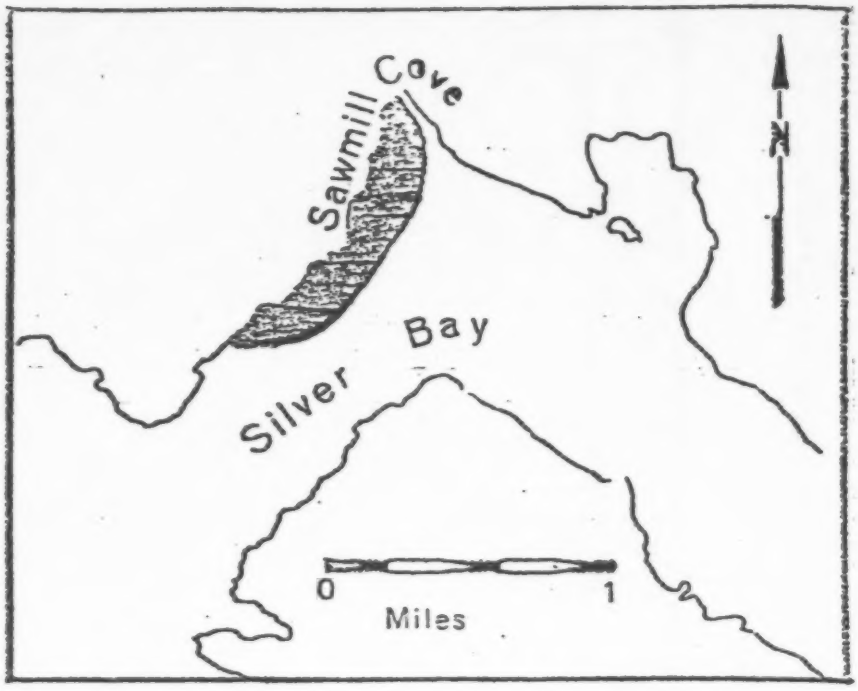

Figure 10 Silver Bay sludge deposits

Silver Bay reach adjacent to this cove revealed no apparent change in the extent and location of the sludge bed found in the previous study. Chemical data from five bottom samples sent for laboratory analyses following the 1974 survey show four of these sludges still had high percentages of volatile solids, organic carbon, organic nitrogen, and sulfides that greatly exceeded the above criteria (Table 5). The four samples (Stations 36, 15, 16, and 19) that exceed these criteria were collected from the sludge deposits depicted in Figure 10, and the sample from Station 13, which did not exceed these criteria, was

TABLE 5

CHEMICAL AND PHYSICAL CHARACTERISTICS OF SAWMILL COVE AND SILVER BAY SEDIMENTS

SEPTEMBER 1974

STATION NUMBER*	TOTAL SOLIDS (% OF WET WEIGHT)	TOTAL VOLATILE SOLIDS (% OF TOTAL SOLIDS)	TOTAL ORGANIC CARBON (% DRY WEIGHT)	TOTAL ORGANIC NITROGEN (% DRY WEIGHT)	TOTAL SULFIDES (% DRY WT)
13	67.1	4.6	3.1	0.04	0.12
36	17.8	69.1	82.6	0.47	0.26
16	13.4	78.3	51.5	0.23	0.47
15	12.9	51.5	89.1	0.93	0.73
19	15.7	58.6	78.3	0.95	0.22

*These are not the precise locations sampled in the 1968-70 study, but are quite close.

from a bottom reach of Silver Bay that was not covered with sludge. Station 13 is located off the mouth of the dugway that diverts Sawmill Creek to the eastern sides of Sawmill Cove and Silver Bay; it was not expected to have sludge because of the flushing influence of Sawmill Creek on this portion of the bay. No attempts were made to collect bottom samples from reaches beyond the area of the sludge beds depicted in Figure 10 because this activity was beyond the scope and capability of equipment of the 1974 survey. Nevertheless, it is unlikely that sludge deposits caused by pulp waste discharges are present elsewhere in the Silver Bay-Eastern Channel study area.

From a comparison of the chemical aspects of the deposits sampled during the two survey periods (1968-1970 with 1974), it is concluded that no major change has occurred in the chemical composition of the sludges in Sawmill Cove and the adjacent seaward, northwestern reach of Silver Bay. The lack of such a change is not unexpected, however, because the breakdown of such materials under the anaerobic conditions that prevail therein requires a significantly longer period of time than the two year interval since the installation and operation of the mill's primary treatment facility which is designed to remove most of the settleable solids from its wastewaters.

Visual and Biological Aspects of Bottom Deposits

Visual and biological inspection of samples from the bottom deposits in Sawmill Cove and the adjacent waters of Eastern Channel were considered to be equally important as the sampling of the upper

12 meters of water because, as in the upper 12 meters of water, changes in the visual and biological characteristics of the deposits, if any, would be expected to occur more or less concurrently with changes in the upper 12 meters of water (oxygen-demanding solid pollutants such as wood fibers and other settleable solids contained in the mill effluent prior to the installation and operation of the primary treatment facility would be widely distributed in the surface waters, then slowly settle to the bottom in the study area where some were subsequently re-suspended by bulking processes to again precipitate to the bottom).

It is to be recalled from an earlier section of this report that prior to the operations of the Alaska Lumber and Pulp Company mill the bottom deposits of much of Silver Bay, but not Sawmill Cove, contained perceptible quantities of hydrogen sulfide (1), a compound toxic to many forms of aquatic animals in low concentrations. The same pre-mill study indicated the deep portions of Silver Bay contained very few bottom-associated animals, but a great variety of such organisms, 116 different species in total, were found in intertidal, subtidal and shallow bay reaches. The post-mill study of 1968-1970 however disclosed extensive wood fiber mats covered the darkly colored sludge deposits which also had wood chips. Prominant odors of hydrogen sulfide were apparent in these deposits of Sawmill Cove and the adjacent northwestern shoreline reach of Silver Bay which supported very few animals with most bottom and shoreline reaches con-

taining no macroscopic animals at all.

During the same study, bubbles of hydrogen sulfide gas were observed rising to the surface from these deposits, then bursting. They were a conspicuous feature of the waters throughout almost all of Sawmill Cove, but not as apparent in the adjacent waters of the Silver Bay reach with the sludge deposits. Also conspicuous were small mats of floating wood fibers with some sludge that had bulked and risen to the surface of the cove.*

General observations and biological inspections of samples during the September 1974 survey disclosed no hydrogen sulfide bubbles in the near surface and surface waters above the sludge deposits in either Sawmill Cove or Silver Bay, even though this gas was apparent in many of the sludge samples collected. Also lacking in these surface waters during the September 1974 survey were floating mats of bulked wood fibers and sludge. Bottom samples from the sludge beds did not contain fresh, recently deposited wood fibers, but old wood fibers, small pieces of wood knots, and some wood chips which were found at several stations in the upper reaches of Sawmill Cove and at Station 16 in Silver Bay. Pollution tolerant tube dwelling polychaete worms, found only in a few sludge samples in the 1968-1970 study, were found at several stations in September

*Chemical analyses of one such floating mat following a major fish kill in Sawmill Cove on September 11, 1970 revealed a concentration of 270 mg/l of total sulfides. It had an initial oxygen demand of 320 mg/l and a chemical oxygen demand of 68,400 mg/l (3).

1974 (Stations 13, 15, and 16 in Silver Bay, and several undesignated sites in Sawmill Cove). These September 1974 observations, the lack of recently deposited wood fibers on the sludge beds in the cove and adjacent reach of Silver Bay, the lack of hydrogen sulfide bubbles in surface water reaches above the sludge beds, the lack of floating wood fiber and sludge mats found during the 1968-1970 study, and a perceptible but slight increase in the occurence of pollution tolerant polychaete worms are significant because they reveal that the installation and operation of the primary treatment facility at the mill has resulted in a perceptible general improvement in most of the sludge-affected bottom reaches of Sawmill Cove and Silver Bay. There remained, however, a significant paucity in the variety of bottom associated organisms in these reaches and no major change in the chemical characteristics of the sludge deposits, features indicative that the improvement process is nowhere near complete.

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APPENDIX TABLE 1A

SALINITY WITH DEPTH (METERS) IN SILVER BAY AND ADJACENT WATERS

IN SEPTEMBER 1974

STATION # / DEPTH	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
SEPTEMBER 17, 1974 1130 - 1600 HOURS																							
1	19.74	21.11	20.43	17.67	19.05	16.98	15.53	16.43	13.21	15.60	16.98	16.98	15.94	16.98	17.53	17.67	23.17	25.91	21.11	20.43	21.80	-----	-----
5	23.17	22.49	23.17	23.17	23.17	17.67	17.32	17.32	17.32	16.98	17.67	17.67	17.67	17.67	17.67	17.32	25.22	26.59	25.22	25.22	23.17	-----	17.67
10	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.67	17.67	18.01	17.67	17.67	17.67	17.67	17.32	-----	-----	-----	-----	-----	-----	18.01
12	-----	-----	-----	-----	-----	17.67	17.67	17.67	18.01	17.67	17.67	17.67	17.67	-----	17.67	17.32	-----	-----	-----	-----	-----	-----	17.67
SEPTEMBER 17, 1974 1600 - 1800 HOURS																							
1	-----	-----	-----	-----	-----	16.98	16.29	16.98	16.29	16.29	15.60	16.63	16.98	16.63	16.63	16.98	-----	-----	-----	-----	-----	-----	16.29
5	-----	-----	-----	-----	-----	16.98	16.98	17.67	17.32	17.67	17.67	17.67	17.32	17.32	17.32	16.98	-----	-----	-----	-----	-----	-----	17.67
10	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.32	17.67	16.98	-----	-----	-----	-----	-----	-----	17.53
12	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.32	17.67	16.98	-----	-----	-----	-----	-----	-----	17.67
SEPTEMBER 18, 1974 0930 - 1200 HOURS																							
1	-----	-----	-----	-----	-----	17.12	17.32	15.94	16.29	14.23	16.63	15.60	15.60	15.60	16.63	16.29	20.43	19.74	20.43	18.36	20.43	18.36	14.91
5	-----	-----	-----	-----	-----	17.53	17.32	17.12	17.67	16.98	17.67	17.67	17.67	17.67	17.53	17.67	23.85	22.49	23.85	23.85	23.17	21.11	16.98
10	-----	-----	-----	-----	-----	17.67	17.32	17.32	17.67	17.32	17.32	17.67	17.67	17.67	17.67	17.67	-----	-----	-----	-----	-----	-----	17.32
12	-----	-----	-----	-----	-----	17.67	17.32	17.32	17.67	17.32	17.53	17.67	17.67	17.67	17.67	17.67	-----	-----	-----	-----	-----	-----	17.32
SEPTEMBER 18, 1974 1500 - 1830 HOURS																							
1	-----	-----	18.36	17.67	18.36	15.94	16.98	16.98	13.55	15.94	16.98	15.60	18.36	15.60	16.98	15.94	-----	-----	-----	-----	-----	-----	15.60
5	-----	-----	23.85	23.85	25.22	17.67	17.81	17.12	17.32	17.67	17.67	18.36	18.36	17.67	17.67	17.67	-----	-----	-----	-----	-----	-----	18.01
10	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.67	17.67	17.67	15.60	18.36	17.67	18.36	17.67	-----	-----	-----	-----	-----	-----	17.67
12	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.81	18.01	17.67	17.67	18.36	17.67	18.36	17.67	-----	-----	-----	-----	-----	-----	18.70

APPENDIX TABLE 2A

SALINITY WITH DEPTH (METERS) IN SILVER BAY AND ADJACENT WATERS

IN SEPTEMBER 1974

STATION # / DEPTH	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
SEPTEMBER 17, 1974 1130 - 1600 HOURS																							
1	19.74	21.11	20.43	17.67	19.05	16.98	15.53	16.43	13.21	15.60	16.98	16.98	15.94	16.98	17.53	17.67	23.17	25.91	21.11	20.43	21.80	-----	-----
5	23.17	22.49	23.17	23.17	23.17	17.67	17.32	17.32	17.32	16.98	17.67	17.67	17.67	17.67	17.67	17.32	25.22	26.59	25.22	25.22	23.17	-----	17.67
10	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.67	17.67	18.01	17.67	17.67	17.67	17.67	17.32	-----	-----	-----	-----	-----	-----	18.01
12	-----	-----	-----	-----	-----	17.67	17.67	17.67	18.01	17.67	17.67	17.67	17.67	-----	17.67	17.32	-----	-----	-----	-----	-----	-----	17.67
SEPTEMBER 17, 1974 1600 - 1800 HOURS																							
1	-----	-----	-----	-----	-----	16.98	16.29	16.98	16.29	16.29	15.60	16.63	16.98	16.63	16.63	16.98	-----	-----	-----	-----	-----	-----	16.29
5	-----	-----	-----	-----	-----	16.98	16.98	17.67	17.32	17.67	17.67	17.67	17.32	17.32	17.32	16.98	-----	-----	-----	-----	-----	-----	17.67
10	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.32	17.67	16.98	-----	-----	-----	-----	-----	-----	17.53
12	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.32	17.67	16.98	-----	-----	-----	-----	-----	-----	17.67
SEPTEMBER 18, 1974 0930 - 1200 HOURS																							
1	-----	-----	-----	-----	-----	17.12	17.32	15.94	16.29	14.23	16.63	15.60	15.60	15.60	16.63	16.29	20.43	19.74	20.43	18.36	20.43	18.36	14.91
5	-----	-----	-----	-----	-----	17.53	17.32	17.12	17.67	16.98	17.67	17.67	17.67	17.67	17.53	17.67	23.85	22.49	23.85	23.85	23.17	21.11	16.98
10	-----	-----	-----	-----	-----	17.67	17.32	17.32	17.67	17.32	17.32	17.67	17.67	17.67	17.67	17.67	-----	-----	-----	-----	-----	-----	17.32
12	-----	-----	-----	-----	-----	17.67	17.32	17.32	17.67	17.32	17.53	17.67	17.67	17.67	17.67	17.67	-----	-----	-----	-----	-----	-----	17.32
SEPTEMBER 18, 1974 1500 - 1830 HOURS																							
1	-----	-----	18.36	17.67	18.36	15.94	16.98	16.98	13.55	15.94	16.98	15.60	18.36	15.60	16.98	15.94	-----	-----	-----	-----	-----	-----	15.60
5	-----	-----	23.85	23.85	25.22	17.67	17.81	17.12	17.32	17.67	17.67	18.36	18.36	17.67	17.67	17.67	-----	-----	-----	-----	-----	-----	18.01
10	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.67	17.67	17.67	15.60	18.36	17.67	18.36	17.67	-----	-----	-----	-----	-----	-----	17.67
12	-----	-----	-----	-----	-----	17.67	17.67	17.67	17.81	18.01	17.67	17.67	18.36	17.67	18.36	17.67	-----	-----	-----	-----	-----	-----	18.70

APPENDIX TABLE 3A

SULFITE WASTE LIQUOR CONCENTRATIONS (MG/L)
WITH DEPTH (METERS) AT SELECTED STATIONS IN SILVER BAY AND EASTERN CHANNEL, 1968 - 1970

STATION NUMBER	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
DEPTH									MARCH 28, 29, 31, 1968														
1	-	-	-	-	-	23	17	-	252	-	14	69	576	-	-	102	45	17	39	-	86	17	-
5	-	-	<5	<5	7	-	-	-	8	-	<5	<5	5	-	-	-	6	5	<5	-	13	<5	-
									JULY 24, 1968														
1	-	-	-	-	-	228	388	-	291	447	278	545	1930	191	-	533	202	336	113	133	99	88	-
									JULY 27, 1968														
1	-	-	156	136	229	288	290	-	261	260	31	190	176	67	-	111	484	321	141	185	268	136	-
5	-	-	-	-	-	-	-	-	<5	18	7	17	33	-	-	10	-	-	-	-	-	-	-
									OCTOBER 12, 13, 14, 1968														
1	-	-	<5	<5	-	-	-	10	-	-	-	-	180	-	7	-	30	63	48	-	-	8	-
5	-	-	<5	<5	-	-	-	<5	-	-	-	-	<5	-	<5	-	<5	<5	<5	-	-	<5	-
10	-	-	<5	<5	-	-	-	<5	-	-	-	-	<5	-	<5	-	<5	<5	<5	-	-	<5	-
									DECEMBER 13, 14, 15, 1968														
1	-	-	<5	<5	-	-	-	<5	-	-	-	-	218	-	146	-	19	170	-	-	-	34	-
5	-	-	<5	<5	-	-	-	<5	-	-	-	-	7	-	6	-	7	58	-	-	-	24	-
10	-	-	<5	<5	-	-	-	<5	-	-	-	-	<5	-	<5	-	<5	<5	-	-	-	7	-
									APRIL 22, 23, 1969														
0	8	14	<5	6	-	-	-	12	-	-	-	-	952	-	124	-	61	77	53	-	-	191	-
5	-	-	<5	<5	-	-	-	<5	-	-	-	-	11	-	10	-	21	11	26	-	-	21	-
10	-	-	<5	<5	-	-	-	<5	-	-	-	-	<5	-	<5	-	<5	<5	<5	-	-	-	-
									AUGUST 20, 1970														
1	-	-	-	-	-	-	-	-	-	215	-	-	1885	-	-	-	-	-	-	-	-	-	495
5	-	-	-	-	-	-	-	-	-	7	-	-	32	-	-	-	-	-	-	-	-	-	15
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11

APPENDEX TABLE 4A

MAXIMA, MINIMA, RANGE AND AVERAGE DISSOLVED OXYGEN (D.O.) CONCENTRATIONS (MG/L) AT STATIONS 12 - 16 IN SILVER BAY DURING JULY, AUGUST AND SEPTEMBER, BEFORE AND AFTER OPERATION OF PRIMARY TREATMENT FACILITIES AT ALASKA LUMBER AND PULP COMPANY, 1972 AND 1974*

	BEFORE PRIMARY TREATMENT			AFTER PRIMARY TREATMENT		
STATION NUMBER	RANGE IN MINIMUM D.O. CONC.	RANGE IN MAXIMUM D.O. CONC.	AVERAGE CONCENTRATION	RANGE IN MINIMUM D.O. CONC.	RANGE IN MAXIMUM D.O. CONC.	AVERAGE CONCENTRATION
	JULY, AUGUST, SEPTEMBER 1972 ONE METER DEPTH			JULY, AUGUST, SEPTEMBER 1974 ONE METER DEPTH		
12	4.6 - 5.5	7.0 - 8.0	6.5	6.0 - 7.0	7.4 - 11.1	7.7
13	4.9 - 6.1	6.4 - 8.3	6.4	6.0 - 7.5	8.0 - 11.6	8.0
14	5.3 - 5.8	7.0 - 8.5	6.7	5.7 - 7.6	8.2 - 9.0	7.8
15	3.4 - 5.8	8.7 - 9.4	6.9	5.8 - 7.4	7.7 - 8.8	7.4
16	5.2 - 7.2	8.0 - 9.3	7.4	6.7 - 8.1	8.8 - 12.2	8.7
	FIVE METER DEPTH			FIVE METER DEPTH		
12	6.2 - 7.5	8.1 - 9.6	8.0	8.0 - 9.1	9.2 - 12.2	9.6
13	6.6 - 7.4	8.2 - 9.6	7.9	7.7 - 8.8	8.5 - 11.9	9.5
14	7.0 - 8.7	8.3 - 10.0	8.3	8.3 - 9.4	9.4 - 12.4	9.7
15	7.0 - 7.5	8.0 - 9.7	8.2	8.4 - 9.3	9.4 - 11.6	9.6
16	6.0 - 7.2	7.8 - 9.5	7.9	8.1 - 9.2	9.1 - 12.2	9.6

APPENDIX TABLE 5A
RANGE IN DISSOLVED OXYGEN CONCENTRATIONS (MG/L) AT 1 AND 5 METER DEPTHS
AT STATIONS 12 THROUGH 16 IN SILVER BAY ALASKA
FROM JULY 1972 TO SEPTEMBER 1974*

STATION NUMBER	12	13	14	15	16	12	13	14	15	16
MONTH	1 METER DEPTH					5 METER DEPTH				
JULY	4.6- 8.0	6.1- 8.3	5.3- 7.0	3.4- 9.4	7.2- 9.3	7.3- 9.6	7.4- 9.6	8.7-10.0	7.5- 9.7	7.2- 9.5
AUGUST	5.2- 7.0	5.1- 6.4	5.8- 8.5	5.8- 8.7	5.8- 8.8	6.2- 8.6	7.2- 8.7	7.0- 8.3	7.0- 9.5	6.9- 8.8
SEPTEMBER	5.5- 7.4	4.9- 7.2	5.8- 8.0	5.7- 8.9	5.2- 8.0	7.5- 8.1	6.6- 8.2	7.1- 8.6	7.3- 8.0	6.0- 7.8
OCTOBER	6.3-10.1	5.6-11.4	7.7-11.3	7.1-10.7	6.1-10.0	7.4- 9.9	7.4- 9.7	8.1- 9.5	8.1- 9.7	8.1- 9.7
NOVEMBER	7.8- 9.8	7.1- 9.8	8.1-10.5	7.9-10.3	6.8- 9.8	7.9- 9.3	7.8- 9.2	8.2-10.5	8.3-10.4	8.0- 9.6
DECEMBER	7.9- 9.4	8.0- 9.7	8.3- 9.4	7.7- 9.8	7.5- 9.3	7.7- 9.8	8.5- 9.7	8.5- 9.8	8.7- 9.9	7.8- 9.2
JANUARY	8.6-10.7	9.2-10.3	8.6-11.3	8.6-10.7	8.0-10.4	8.8-10.6	8.5-10.9	8.1-11.4	8.4-11.0	8.0-11.1
FEBRUARY	7.7- 9.0	7.5-10.5	8.4- 9.2	7.3-10.3	6.6- 8.7	8.5- 8.8	8.3- 8.9	8.9- 9.1	8.5- 8.9	8.3- 8.9
MARCH	6.1-10.4	7.1-10.1	8.0-10.2	7.4-10.1	6.4-10.0	9.3-10.7	9.3-10.5	9.1-10.6	9.0-10.5	8.4-10.4
APRIL	7.4-11.3	8.3-11.5	6.6-11.0	7.5-11.3	9.2-10.9	9.8-11.1	9.4-11.5	9.7-11.5	9.8-10.8	9.6-11.4
MAY	8.3-10.8	8.3-10.7	8.7-11.0	8.3-11.2	8.0-10.4	10.0-11.6	10.3-10.9	10.1-13.4	10.2-12.4	10.3-11.7
JUNE	6.3-10.5	6.4- 9.9	6.1-10.6	6.0- 9.9	6.5-10.2	9.4-10.7	9.6-10.4	9.2-10.8	10.0-11.1	9.2-10.6
JULY a	5.1- 6.2	5.2- 5.9	4.5- 8.3	3.6- 6.8	4.7- 6.6	8.8- 9.1	7.9- 8.7	8.3- 9.9	8.3-10.2	8.7- 9.9
AUGUST b										
SEPTEMBER b										
OCTOBER	6.5- 7.3	6.2- 7.5	7.4- 8.3	6.6- 8.3	6.1- 7.9	6.9- 8.3	7.0- 8.1	7.5- 8.3	6.9- 8.3	7.1- 8.3
NOVEMBER	7.3- 8.2	7.5- 7.8	7.7- 8.6	7.5- 8.3	7.2- 8.2	7.1- 8.3	7.0- 8.0	8.0- 8.5	7.8- 8.3	7.5- 8.5
DECEMBER a	7.6- 7.7	7.7- 7.8	7.3- 7.9	7.5- 7.7	7.0- 7.3	7.6- 7.9	7.7- 7.8	7.4- 7.9	7.4- 7.9	7.8- 7.8
JANUARY	8.4- 8.7	8.3- 8.6	8.7- 9.0	8.3- 8.9	8.1- 8.5	8.3- 8.6	7.9- 8.5	8.5- 9.3	8.4- 8.8	7.9- 8.9
FEBRUARY	8.6- 9.2	8.9- 9.3	9.1- 9.5	9.1- 9.7	8.7- 9.2	9.1- 9.6	8.3- 9.5	8.7-10.1	9.3- 9.5	9.1- 9.5
MARCH	8.6-12.1	8.9-12.5	9.6-12.2	9.2-12.5	8.6-12.1	9.2-12.6	9.0-12.7	9.6-12.5	9.4-12.7	9.3-12.0
APRIL	10.2-13.7	8.2-13.5	12.0-14.6	9.9-14.2	9.6-13.8	10.4-13.8	9.9-13.6	11.4-14.0	9.7-13.4	9.6-14.3
MAY	5.8-10.3	5.4-10.3	5.7-10.9	5.6-12.0	7.7-10.7	7.2-11.6	8.5-11.7	9.2-11.9	9.1-11.7	8.3-11.5
JUNE	6.2- 8.0	6.8- 8.5	7.0- 9.7	4.2- 9.5	7.5- 8.8	9.2-11.0	8.8-12.0	9.0-11.5	9.0-12.2	8.2-11.3
JULY	6.0- 8.9	7.5- 8.0	5.7- 8.2	5.8- 7.9	6.7- 8.9	8.9-10.8	8.8-11.9	8.3-10.2	8.9-10.4	8.8-10.4
AUGUST	6.6-11.1	6.0-11.6	6.9- 9.0	6.2- 8.8	7.7-12.2	9.1-12.2	8.8-11.6	9.4-12.4	9.3-11.6	9.2-12.2
SEPTEMBER c	7.0- 7.4	7.2- 8.5	7.6- 9.0	7.4- 7.7	8.1- 8.8	8.0- 9.2	7.7- 8.5	8.6- 9.4	8.4- 9.4	8.1- 9.1

*Monitoring data from Alaska Lumber and Pulp Company, required weekly by Alaska Department of Environmental Conservation Permit Number 71-2.

a. Only two sets of determinations were made during the month.
b. Pulp mill workers were on strike, mill not operating from July 12 to September 27, 1973.
c. Values do not include data obtained later than 20th of month.

APPENDIX TABLE 6A

pH VALUES AT DEPTH (IN METERS) AT SILVER BAY AND EASTERN CHANNEL

SEPTEMBER 1974

STATION NUMBER	1	2	3	4	5	6	7	8	12	13	14	15	16	20	21	22	23	24	25	26	27	28	36
SEPTEMBER 17, 1974 1130 - 1600 HOURS																							
DEPTH																							
1	7.3	7.6	7.2	7.5	7.7	7.5	7.5	7.5	7.4	7.5	7.5	7.6	7.4	7.7	7.6	7.6	7.3	7.4	7.6	7.9	8.2	8.2	7.5
5	7.7	7.9	7.6	7.8	7.9	7.5	7.6	7.5	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.7	7.4	7.9	7.7	8.0	8.4	8.3	7.6
10	-	-	-	-	-	7.5	7.6	7.5	7.6	7.6	7.6	7.6	7.6	7.7	7.7	7.7	-	-	-	-	-	-	7.6
12	-	-	-	-	-	7.5	7.6	7.5	7.6	7.6	7.6	7.6	7.6	7.7	7.7	7.7	-	-	-	-	-	-	7.6
SEPTEMBER 17, 1974 1600 - 1800 HOURS																							
1	-	-	-	-	-	7.6	7.6	7.6	-	7.6	7.7	7.6	7.5	7.7	7.7	7.6	-	-	-	-	-	-	7.6
5	-	-	-	-	-	7.6	7.5	7.6	7.7	7.6	7.7	7.7	7.7	7.7	7.7	7.7	-	-	-	-	-	-	7.7
10	-	-	-	-	-	7.5	7.7	7.7	7.7	7.7	7.7	7.6	7.7	7.7	7.7	7.7	-	-	-	-	-	-	7.7
12	-	-	-	-	-	7.6	7.7	7.6	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	-	-	-	-	-	-	7.7
SEPTEMBER 18, 1974 0930 - 1200 HOURS																							
1	-	-	-	-	-	7.7	7.8	7.8	7.6	7.7	7.8	7.6	7.8	7.7	7.7	7.7	7.5	7.0	7.7	7.7	7.6	7.5	7.7
5	-	-	-	-	-	7.8	7.8	7.8	7.8	7.8	7.8	7.7	7.8	7.8	7.8	7.8	9.0	8.1	7.9	7.9	7.9	7.7	7.7
10	-	-	-	-	-	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	-	-	-	-	-	-	7.8
12	-	-	-	-	-	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	-	-	-	-	-	-	7.8
SEPTEMBER 18, 1974 1500 - 1830 HOURS																							
1	-	-	8.6	8.0	9.2	7.8	7.8	7.8	7.8	7.8	7.8	7.7	7.9	7.7	7.8	7.7	-	-	-	-	-	-	7.8
5	-	-	8.6	9.0	9.0	7.8	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.8	-	7.8	-	-	-	-	-	-	7.8
10	-	-	-	-	-	7.8	7.9	7.8	7.8	7.8	7.8	7.7	7.8	7.9	7.8	7.8	-	-	-	-	-	-	7.8
12	-	-	-	-	-	7.8	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.9	7.8	7.8	-	-	-	-	-	-	7.8